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THE OCEAN AND THE FUTURE

HEARINGS

BEFORE THE

SUBCOMMITTEE ON OCEANOGRAPHY

OF THE

COMMITTEE ON
MERCHANT MARINE AND FISHERIES
HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

ON

MARINE BIOTECHNOLOGY
JULY 15, 1985—BALTIMORE, MD

NOAA'S OCEAN MINERALS PROGRAM AND THE REAUTHORIZATION OF THE DEEP SEABED HARD MINERAL RESOURCES ACT
OCTOBER 24, 1985

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CONTENTS

MARINE BIOTECHNOLOGY

Page

- Hearing held July 15, 1985, Baltimore, MD 1
- Statement of:
  - Berkowitz, Bernard, president, Baltimore Economic Development Corp 4, 15
    - Prepared statement 16
  - Colwell, Dr. Rita, vice president for academic affairs, University of Maryland 4
    - Prepared statement 7
  - Embry, Bob, of Cordish Embry & Associates, Baltimore, MD 4, 14
  - Karuna-Karan, Dr. Arthur, president, Cyano-Tech Corp., Woodinville, WA 24, 34
    - Prepared statement 36
  - Kraeuter, Dr. John, Baltimore Gas & Electric 24
  - Lowry, Hon. Mike, a Representative in Congress from the State of Washington 21
  - Mikulski, Hon. Barbara A., a Representative in Congress from the State of Maryland, and chairwoman, Subcommittee on Oceanography 1
  - Miller, Hon. John R., a Representative in Congress from the State of Washington 3
  - Poindexter, Chris, vice president, Baltimore Gas & Electric 24
  - Portier, Dr. Ralph, Louisiana State University 24, 38
  - Shumway, Hon. Norman D., a Representative in Congress from the State of California 3
  - Sullivan, James J., California Sea Grant College Program 56
  - Trueschler, Bernard C., chairman of the board, Baltimore Gas & Electric Co. (prepared statement) 27
- Additional material supplied:
  - Colwell, Dr. Rita:
    - Article: "Sea Grant: A Capability for Biotechnology Research" 10
    - University of Maryland, Center of Marine Biotechnology: A task force report 74
  - Portier, Dr. Ralph: Attachments to statement 41
  - Sullivan, James J.: University of California Biotechnology Research and Education Program 68

NOAA'S OCEAN MINERALS PROGRAM AND THE REAUTHORIZATION OF THE DEEP SEABED HARD MINERAL RESOURCES ACT

- Hearing held October 24, 1985 85
- Statement of:
  - Bosco, Hon. Douglas H., a U.S. Representative from California 87
  - Broadus, James, economist, Woods Hole Oceanographic Institution 129
    - Prepared statement 132
  - Curtis, Clifton, president, Oceanic Society 176
    - Prepared statement 177
  - Greenwald, Richard J., secretary and general counsel, Deepsea Ventures, Inc., and Ocean Mining Associates 190
    - Prepared statement 192
  - Knecht, Robert W., consultant in ocean and coastal policy 196
    - Prepared statement 198
  - Mikulski, Hon. Barbara A., a U.S. Representative from Maryland 85
  - Nordquist, Myron, attorney 168
    - Prepared statement 170
      - Appendix to prepared statement 172

READEX FICHE

Statement of—Continued | Page
Peck, Dallas, Director, U.S. Geological Survey 185
Prepared statement 186
Shumway, Hon. Norman D., a U.S. Representative from California 86
Welling, Conrad, Ocean Minerals Co 121
Prepared statement 123
Wolff, Paul M., Assistant Administrator for Ocean Services and Coastal Zone Management, NOAA 116
Prepared statement 118
Additional material supplied:
Bosco, Hon. Douglas H.: H.R. 2048 89
Communication submitted:
Subcommittee staff: Memorandum of October 17, 1985, to members of the Subcommittee on Oceanography 93

MARINE BIOTECHNOLOGY

MONDAY, JULY 15, 1985

House of Representatives,
Subcommittee on Oceanography,
Committee on Merchant Marine and Fisheries,
Baltimore, MD.

The subcommittee met, pursuant to call, at 9:30 a.m., at the National Aquarium, Harbor View Room, Inner Harbor, Baltimore, MD, Hon. Barbara A. Mikulski (chairwoman of the subcommittee) presiding.

Present: Representatives Mikulski, Lowry, Shumway, and Miller.

Ms. Mikulski. Good morning, everybody.

OPENING STATEMENT OF HON. BARBARA A. MIKULSKI, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF MARYLAND, AND CHAIRWOMAN, SUBCOMMITTEE ON OCEANOGRAPHY

Ms. Mikulski. I would like to welcome all of you to the first in what will be a series of hearings this subcommittee plans to hold on the ocean and the future.

It is with great pride that I welcome my subcommittee colleagues and other guests here today. I want to particularly acknowledge the director of the aquarium, Mr. Nick Brown, who is in the audience, and thank him for providing us with this unique setting for our first hearing, and his staff, especially Mrs. Shirly Polikoff.

I cannot think of a more fitting setting to hold this hearing than the National Aquarium. I was a member of the Baltimore City Council that established the legislative framework to create the aquarium.

I remember that over a decade ago, people with vision spoke of this new biotechnology and of the great things that can be accomplished here.

Where we are sitting now, the city fathers in the 1960's planned a 16-lane highway coming through the west side and eliminating the oldest ethnic communities in Baltimore.

Over there is Federal Hill, a bit like Baltimore's Georgetown on the waterfront. That was viewed as an engineering obstacle that was going to be leveled to get commuters in and out of the city.

The people of Baltimore rallied through their neighborhoods to protest the expressway.

I must confess, though you find it hard to believe, I helped lead the protest movement. In that process, I never thought that 15 years later, we would be here holding a hearing on new growth industries within sight of a city that rehabilitated itself.

Under the leadership of Mayor Schaefer, whose philosophy is, if you have a lemon, turn it into lemonade, we came up with a concept that includes the World Trade Center and the National Aquarium.

The job of the National Aquarium was to do two things, be a tourist attraction, and also be a center for research and education. Here within this setting we hope that we can see what are some of the new opportunities for the future.

Our witnesses today will be talking about ocean-related industries that offer potential opportunities for entrepreneurism, growth in new jobs.

Our witnesses today will present some very exciting testimony about biotechnology. John Naisbitt, in his book, Megatrends, states that the next 20 years will be the age of biology in the way that the last 20 years have been the age of microelectronics.

After today's hearing, I think all of us will better understand some of the new frontiers that await us—new frontiers like gene splicing, which will be as important to us in the 21st century as atom-splitting was to us in exploring the new frontiers of the space age.

Our subcommittee is interested in learning how the ocean's resources can be used in developing new technologies that will help us solve some of the gigantic problems facing our oceans and the nations of the world—problems like pollution and hunger.

This morning, we want to do several things. First, we want to define what marine biotechnology is. Second, we want to learn what economic opportunities it offers. We also want to lay out for discussion some questions that will ultimately need answering:

What role, if any, should Government play in developing these new industries?

Is present-day, Government-sponsored R&D sufficient?

Should there be increased incentives for private sector R&D?

What role should Government play in safeguarding the public health?

Hopefully, after this hearing and others are held, an agenda will be formulated. Today is just the beginning. Today we are starting to put together a framework for the future through which we can develop our ocean resources to build new growth industries. And at the same time, preserve and protect our natural resources for future generations.

The American inventor and futurist, Charles Kettering, once said, "We should all be concerned about the future because we will all have to spend the rest of our lives there."

The future is going to be an exciting place to be. I look forward to working with my colleagues and with experts and entrepreneurs around the country in finding some of the best ways to get us there.

I would like to introduce my panel, but before I do, I will ask for opening statements that my colleagues might have. I would like to introduce the members present here today. First, Congressman Norman Shumway, my ranking minority counterpart, who has worked assiduously on a bipartisan basis on this committee.

OPENING STATEMENT OF HON. NORMAN D. SHUMWAY, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF CALIFORNIA

Mr. **Shumway**. Thank you, Madam Chairwoman.

I appreciate the opportunity to be here today. The future is an exciting place to be, but today, there can be no more exciting place to be than here in the Inner Harbor in Baltimore, and I appreciate the history you gave us.

The topic for today is a topic which is new to me, and, I suppose relatively new to all of us. It holds a great deal of social and economic promise for our Nation in terms of producing new products that will accomplish a very wide range of benefits from treating diseases to cleaning up environmental contamination, along with many other things that may be very useful for our society.

It is a very rapidly growing and changing area, and I think, therefore, there is a very keen role for us as Americans to play in terms of establishing the leadership of our Nation, getting out in front on projects and funding programs and extending our knowledge into these new realms of activity.

I am particularly interested in this morning's topic because of the tremendous interest in this subject in my own State of California, where one-third of our Nation's biotechnology firms are located already. Obviously, then, what we do in this hearing this morning and in the future will be of great interest to them.

To quote from a regulatory review on biotechnology, prepared by the California Assembly Office of Research, "Biotechnology is expected to be a dominant, new technology affecting many industries over the next quarter-century, much the same as information processing has been dominant for several decades. California stands to gain enormously from the jobs and revenues produced by the economic revolution in biotechnology."

Of course, the widespread potential application of this technology raises many questions regarding Government's role, both in terms of aiding biotech research efforts and regulating industrial applications.

A White House Cabinet Council Working Group, comprised of 17 Federal agencies, recently published a "Proposal for a Coordinated Framework for Regulation of Biotechnology." I look forward to hearing today's testimony from our distinguished witnesses, and particularly, any comments they might have on this regulatory proposal.

I would like to welcome this morning's witnesses, particularly Dr. Jim Sullivan, the director of the Sea Grant Program in my home State of California.

Thank you, Madam Chairwoman.

Ms. **Mikulski**. Congressman Miller from Washington.

OPENING STATEMENT OF HON. JOHN R. MILLER, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF WASHINGTON

Mr. **Miller**. Madam Chairman, in my brief 6 months in Congress, I don't think that I have been at a hearing or a meeting in such a place as this.

I will try to focus on the witnesses in front of us this morning instead of on the harbor. It is magnificent.

I am delighted that under your leadership and the leadership of Congressman Shumway, we are going to be entering into this new field. I read some of the papers the committee staff prepared, and I must confess that there was much that I was not able to fathom, but hopefully in the next several months, some of the lingo of the marine biotechnology field will become more understandable.

I am excited about these hearings, and I am also excited because one of the corporations that is on the cutting edge in this field is Cyanotech, located in Woodville, WA, my district, so I look forward to today's hearings, and hearing from the president of that corporation, and the other witnesses that you have today.

Ms. MIKULSKI. Thank you very much.

We would like now to call the witnesses before the committee. The first panel consists of Dr. Rita Colwell, Mr. Bob Embry, and Mr. Bernard Berkowitz.

Dr. Colwell is the vice president for academic affairs at the University of Maryland and also the driving force behind forming a major biotechnology triad at the University of Maryland, of which marine biology is one of the components. She is internationally renowned in that field.

Mr. Robert Embry, now in the private sector, was former Assistant Secretary of HUD, and was the head of housing and economic development for Mayor Schaefer, who is the prime mover behind this architectural framework.

And Mr. Bernard Berkowitz, president of the Baltimore Economic Development Corp., to give a cameo of what it means to generate an idea and tie in with the university in its economic development applications.

What is biotechnology?

STATEMENTS OF DR. RITA COLWELL, VICE PRESIDENT FOR ACADEMIC AFFAIRS, UNIVERSITY OF MARYLAND; BOB EMBRY, CORDISH EMBRY & ASSOCIATES, BALTIMORE, MD; AND BERNARD BERKOWITZ, PRESIDENT, BALTIMORE ECONOMIC DEVELOPMENT CORP.

Dr. COLWELL. Thank you; it is a pleasure to speak to the committee to talk about marine biotechnology. I have prepared a statement and provided materials which I should like to enter into the record.

I should like to speak to you extemporaneously.

Ms. MIKULSKI. Your entire statement will be entered into the record.

Dr. COLWELL. Thank you.

As you are aware, we are now in the midst of another technological explosion, a revolution. The biotechnology research carried out in recent years has been really the exploitation of new techniques in microbiology, and molecular biology, that permit the utilization of genetic material and transfer into organisms which would otherwise not be able to incorporate that genetic material, so that now new combinations of genetic material are possible.

In order to take your attention away from the beautiful view of Baltimore Harbor, I wish to show a few slides to focus your attention, if I may, to emphasize the beautiful simplicity of biotechnology and expound on the applications in marine biotechnology.

Ms. MIKULSKI. Just think what Copernicus could have done if he had slides.

Dr. COLWELL. As a professor, one finds videographics very helpful. To provide some background, biotechnology has already had a significant impact on the U.S. economy.

In less than 10 years, some $2.5 billion have been invested in setting up new companies dedicated to developing products from biotechnology.

Very simply, the techniques of biotechnology, that is, genetic engineering, involve cutting genetic material with enzymes, like a pair of scissors and linking those little snippets of genetic material using other enzymes, and incorporate them into the genetic material of other organisms so one bypasses the need for mating and selection. Within a matter of hours or days, one can produce an entirely new organization of the genes.

It means that over the last 100 years of exploration of the oceans, during which discoveries have been made of unusual antibiotics and unusual pharmacologically active compounds, including hormones controlling the growth of fish, the genes that code for these activities can now be excised, placed into bacteria in a laboratory and the material produced without having to harvest or exploit the animals, plants, coral reefs et cetra, to collect the organisms, without having to completely deplete populations of rare, but important species.

One can take the genetic material, excise it with enzymes, and insert it into bacteria that one can grow in the laboratory. This means we have access to the entire genetic complement of the world's oceans, 70 percent of the surface of the Earth. Extraordinarily unusual organisms have been discovered in the last decade, organisms that can grow at 150° C. under high hydrostatic pressure, as one example of a recent, exciting discovery.

This means new forms of life, as well as enzymes that are efficient and active in bioengineering processes that require high temperature and high pressure, are now available.

It means we have access to economically important material. In California, a group at the University of California at Santa Barbara, has been able to produce at will, spawning of the abalone, by adding trace amounts of hydrogen peroxide.

We have been able to do the same kind of research with the Chesapeake Bay oyster, using oyster spat ready to settle.

The genes that control the growth of these animals, the abalone in California, the salmon in Washington State, and the oyster and the crab in Chesapeake Bay, these genes can now be cloned into bacteria and the hormones coded by the genes can be produced in the laboratory.

Perhaps we may one day be able to develop the super oyster, the super salmon, but, to be serious, what this development in marine biotechnology means is that we can have a faster rate of growth of commercially important fish and shellfish, a larger harvest, and a shorter growing period, in short, a revolution in aquaculture.

Seaweed culture, in China and other countries of Asia is important. Seaweeds are a major food staple for many countries in Asia.

By genetic improvements in seaweeds, we can also provide for an appropriate technology for developing nations that will provide for the food needs of those countries.

In the United States, at Northeastern University, Dr. Don Cheney has developed a technique for fusing cells of seaweed species to produce new hybrids, faster growing and with selected genetic traits. In essence, Dr. Cheney digests the fronds of the seaweeds with enzymes to obtain single cells in culture. These single cells of one species, an abundant producer of an economically important substance, agar or carrageenan, have been fused with cells of seaweeds that grow rapidly. This method of genetic engineering, protoplast fusion, may lead to rapid production of seaweeds which produce the very important economic substance, agar and carrageenans.

All of us have used those substances sometime in our lives. Yogurt may contain agar or carrageenan, as do most toothpastes. We have depended on harvesting these products by the crude techniques of raking them from seawater, bringing them back on barges and purifying them in factories.

In the near future it may be possible to clone genes in the laboratory, and, from that step, have an abundant source of production of the pure agar or carrageenan in the laboratory.

One other area of marine biotechnology which I should like to mention, and which I have not covered in my testimony, because I have just returned from overseas, visiting the United Kingdom, and Europe, where I learned that, the United Kingdom is investing extensively in bioelectronics. The biosensors found in the sea may prove to be a source of very important biodetectors, useful for detecting submarines if the necessary research and development is done, as well useful for detecting pollutants in the air or water. Such detection devices could be very important for public health and perhaps even national security.

It behooves us to consider bioelectronics and biosensors operative in marine organisms as an important model for long-range objectives to consider in marine biotechnology.

The Japanese have made some extraordinary advances in aquaculture and marine biotechnology applications. Cloning of the growth hormone in salmon was announced simultaneously by Japanese and American investigators.

In summary, Marine biotechnology is an area that I could discuss indefinitely because of its very exciting potential. Obviously, we haven't the time now but it is a very important and exciting area of research. The availability to produce new biologicals from marine sources that can block the action of venoms of snakes, scorpions, spiders, even the simple bee, can be produced. New pharmacologically important agents useful in treating cancer and virus infections are being discovered in marine organisms.

We can also produce new chemicals from the sea. Already isolated and in clinical trial are drugs from marine animals that act against the Herpes simplex virus, and against leukemia viruses.

Thus, agents for treating cancer and viral diseases that cannot be treated otherwise, are now possible.

Clearly, marine biotechnology is an area of research and an opportunity that we must not lose. Thank you.

[The statement of Dr. Colwell follows:]

STATEMENT BY DR. RITA COLWELL, VICE PRESIDENT FOR ACADEMIC AFFAIRS AND PROFESSOR OF MICROBIOLOGY, UNIVERSITY OF MARYLAND

Thank you and good morning. I am Rita Colwell, Vice President for Academic Affairs of the University of Maryland and Professor of Microbiology in the Department of Microbiology, University of Maryland, College Park.

I appreciate the opportunity to appear before you today to present a brief overview of the status and potential of marine biotechnology and genetic engineering. I am particularly pleased and encouraged that you have taken the leadership role in examining this extremely important and exciting field of marine science research. Marine biotechnology is truly a revolutionary field in the marine sciences and in the utilization of marine resources and you are to be congratulated on holding the first hearing focused on marine biotechnology.

Biotechnology can be simply defined as the application of engineering principles to biological processes, including the manipulation of genes among organisms to enhance the potential of those processes. Surpassing its age-old foundations in such techniques as the rhetting of flax and the curing of cheese, biotechnology's new attraction derives from discoveries made largely within the past decade.

In the past, classical methods of genetic manipulation have been tedious, requiring the breeding of plants and animals over several generations. Now conventional pollination or fertilization can be by-passed, since the genetic materials, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) can be extracted, purified, and cut into fragments by specific enzymes, allowing genes residing on those fragments to be inserted into a new host plant or animal. The time scale has been compressed and the reach into the gene pool vastly extended.

These techniques allow excision of gene coding for specific functions from one organism—whether plant, animal, or microbe—and transference to another organism—such as a bacterium or yeast, where amplification of the expression of the gene (or genes) can be controlled. Thus, growth hormones for salmon and oyster can be produced in abundance, either in the test tube or, if cloned into the salmon or oyster, by the animal itself in greater quantity.

Because of the progress in marine and ocean research there exists a strong foundation for exploitation of biologically active compounds already known to occur in the sea and for further exploration into the recesses of the world's oceans for compounds and food sources as yet undiscovered. We now have access to an untapped gene pool representing transport systems for minerals, for metal concentration, for novel photosynthetic systems, for marine pheromones (i.e., "communicator substances" produced by marine animals), as well as for the hydrogen sulfide utilizing and microbially mediated system of the Galapagos Vent ecosystems. This wealth of genetic information, once mobilized, will provide new knowledge of the earth's oceans and of ourselves.

Biotechnology in general has already had a sizeable impact on the U.S. economy. In less than ten years, some $2.5 billion has been invested in setting up new companies dedicated to developing products from biotechnology. Monoclonal antibody products have an estimated value of between $20–30 million today with predictions of a $1 billion monoclonal industry by 1990. Genetically manipulated seeds for plants have been projected to increase from $8 million in 1985 to $7 billion by 2000. Amino acids which are produced either by specific microorganisms or by employing specific enzymes produced by microorganisms have been, and will continue to be, compounds needed in increased quantities. For example, phenylalanine, one of the two amino acids which make up the sugar substitute, aspartame, has increased in market value from $7.4 million in 1979 to approximately $100 million in 1984. Analysts predict that the world-wide market for phenylalanine will increase to more than $400 million by 1990.

Most biotechnology research has used terrestrial life for its base. The forecasts of economic development and the prospects for application to agriculture, medicine, and industry are also based on terrestrial biotechnology. The potential for tapping marine life for equivalent efforts is enormous, though such efforts have been slow to develop. It is with the development of marine biotechnology that prospects for new scientific understanding of the vast wealth of ocean life and resultant economic benefits for man have extraordinary potential for the future.

Marine biotechnology, then, refers to the manipulation of marine organisms for improving goods and services to benefit humankind.

The world's oceans cover approximately seventy percent of the earth's surface. Apart from conventional fish harvesting, only in recent years has attention been directed seriously to the marine environment as a storehouse of a range of resources. As technology has allowed scientists to explore the ocean's depths, new and exciting discoveries have surfaced. The discovery of deep-sea thermal vents and the organisms which inhabit these deep ocean regions generated a great deal of interest within the scientific community. The existence of abundant and active organisms in such thermal regions has demonstrated to scientists that the metabolic potential of organisms is virtually unlimited. For example, recent reports of bacteria living in extremely hot water (more than 250 degrees Celcius)—collected from thermal vents—suggest the possibility for developing a new enzyme-based chemical technology especially applicable to high-heat industrial uses.

Some of the specific ongoing and potential research areas in the field of marine biotechnology include: Drugs from marine sources to block the action of venoms from snakes, scorpions, spiders, and bees. Production of new synthetic chemicals modelled on naturally occurring marine toxins for research and commerical applications. Industrial chemicals derived from natural marine products that are already used in the food industry, e.g., xanthans, carrageens, gums, and agar. Specifically engineered marine bacteria to improve treatment of industrial and domestic wastes before discharge into natural waters. Rapid and specific diagnostic tests for fish pathogens using monoclonal antibodies. Production of vaccines by recombinant DNA techniques. Sensitive biological indicators of those adverse environmental conditions which compromise fish resistance. Genetic markers for determining accurate stock assessments of anadromous fish for use by resource management. Phamaceuticals from marine organisms that may be effective against human disease. Genetically engineered bacteria to reduce biofouling of ships, pilings, and other structures in marine environments. Microorganisms engineered to dissolve oil and other pollutants. Development of strains of shellfish and finfish with desirable characteristics for aquaculture. Production of marine polysaccharides as waterproof adhesives.

The potential for research in marine biotechnology and the development of procedures and products based on this research is incredible. Research areas within the field of marine biotechnology are as varied as the regions of the world's oceans. Marine biotechnology can have an impact on all facets of society—from providing new drugs for the treatment of diseases to increasing food production, to providing a means of removing pollutants from the environment.

The application of genetic engineering to the production of fish, mollusks, and crustaceans in hatcheries and natural environments offers unlimited potential. Not only is it possible to make significant advances in applied genetics of foodstock species through laboratory manipulations of the genetic material of these species, it is also possible to realize major advances in production by developing new methods of diagnosis and control of diseases in environments outside the laboratory, such as fish hatcheries.

Marine pharmaceuticals provide researchers in marine biotechnology with a resource that has yet to be significantly investigated. Numerous compounds have been identified with a spectrum of activity range from antibacterial to anticancer to cardictonic and andrenergic, including a wide variety of compounds from the sea which act on the cardiovascular and central nervous systems. Marine natural products (and those of any natural source) of high pharmacologic activity are unsurpassed by synthetic compounds. Researchers actively involved in investigating marine natural products with pharmacologic activity report that only a small fraction of such compounds have been identified and described. In addition to providing a direct source of novel drugs for use in experimental and medical applications, such marine products will serve as models for synthesis or improvement of other drugs.

In this regard, marine toxins are of particular interest. Toxins—physiologically active and often potent—have the potential to be applied either as drugs or as pharmacological reagents. Even marine toxins which may be too toxic for conventional use can serve as model compounds for studying biochemical mechanisms and for developing new compounds.

Significant promise in marine biotechnology concerns the development of methods for controlling the biofouling of ships and other surfaces exposed to ocean water. The presence of biofouling organisms on the hull of a ship, for example, can increase fuel consumption by more than one hundred percent. There is therefore an obvious need for development of methods to control or prevent biofouling. Studies carried out at the University of Maryland have demonstrated that specific marine bacteria may be involved in attacting biofouling invertebrates to surfaces in the marine environment. An understanding of such relationships will aid in the attempt to control the presence and abundance of fouling organisms.

While it is clear that significant progress is being made in realizing the potential of marine biotechnology, we are only beginning. Compared to the efforts in agriculture and medicine, biotechnology research in the marine sciences has been modest. The National Sea Grant College Program of the National Oceanic and Atmospheric Administration has been a major sponsor of marine biotechnology research, with as much as $8 million per year directed to biotechnology research. Many of the examples I have given are the result of Sea Grant efforts. I have included in my statement a brief description of Sea Grant's capability in marine biotechnology.

In testimony before this Subcommittee on February 26, 1985, Dr. John Toll, President of the University of Maryland, described the marine biotechnology initiative developed by the Sea Grant community. I wish to emphasize the point made by Dr. Toll that the success of the Sea Grant initiative will depend on an increased commitment to the essential long-term, high-risk, fundamental research necessary for full development of marine biotechnology. Without additional funds, the already strained Sea Grant budget cannot support the effort needed to truly advance the economic and resource use potential of marine biotechnology.

In conclusion, I wish to briefly describe the newly established Center of Marine Biotechnology at the University of Maryland as an example of the commitment made to marine biotechnology by my institution and the State of Maryland. The purpose of the Center is to advance the application of marine biotechnology through a program of focused research. The State has committed the base funding needed for the initial equipping and staffing of the Center. Through cooperative efforts with industry, federal and state agencies, other academic institutions and the National Aquarium at Baltimore our goal is to expand the Center and to focus on fisheries enhancement, management and production; marine materials and specialty compounds; management of wastes in the marine environment; bioengineering methods development and improvement; marine pharmaceuticals; special applications. We are building upon the wealth of capability and expertise that exists within the University.

University of Maryland research scientists from a number of departments such as botany, chemistry, engineering, medicine, microbiology and zoology provide a broad base of expertise in marine biotechnology. Researchers engaged in marine biotechnology and related projects have already shown promise for application in medicine, aquaculture, and the pharmaceutical industry. For example, the Chesapeake Bay is home to a number of bacteria that are capable of causing disease in humans and in marine organisms. University scientists are applying the techniques of recombinant DNA to understand the pathogenesis of these diseases, to develop diagnostic techniques for detecting their presence in seafood, and to engineer vaccines that will protect against them.

An important research program at the University is focusing on the processes of molluscan larval attachment to surfaces. Researchers have discovered a bacterium, labeled LST, that serves an important role in the attraction, settlement and metamorphosis of oyster larvae. Prospects for developing a chemical attractant capable of inducing larval setting and metamorphosis promise significant improvement in the productivity of oyster hatcheries. A patent is pending on this new bacterium. In related projects, research is underway to genetically engineer this versatile bacteria, not only to elucidate the chemical and biological processes of marine biofouling but also to explore the potential for submarine adhesives and other products.

In other fisheries-related research, scientists at the University of Maryland have isolated a virus implicated in mortalities of Atlantic menhaden and striped bass. Monoclonal antibodies to the virus have been generated and are being used to develop sensitive virus-detection methods for use in hatcheries. Research is also focusing on bacteria found in deep sea thermal vents and toxins and other bioactive compounds from marine organisms. Through the Maryland Sea Grant College work is also underway on the genetic engineering for finfish and the use of mitochondral DNA techniques for obtaining important information of managing the threatened striped bass.

These and numerous other projects construct a solid base from which the University is moving forward in marine biotechnology. By combining expertise in the marine and estuarine sciences, with expertise in chemistry, biochemistry, microbiology, and genetic engineering we have made significant progress with this innovative program in marine-related biotechnology research.

I thank the Subcommittee for its initiative in organizing this hearing and for taking a leadership position in addressing the importance and potential of marine biotechnology.

Thank you.

SEA GRANT: A CAPABILITY FOR BIOTECHNOLOGY RESEARCH

This marine diatom, **Thalassiosira weissflagii**, *shown here 4,000 times actual size, is commonly used in cryopreservation experiments and has great potential for food chain experiments. It also has been successfully grown as food for the larval stages of organisms in mariculture operations.*

Biotechnology, the use of biological systems for the production of goods and services, has expanded rapidly in recent years. The explosive growth of modern biotechnology has been fueled by fundamental breakthroughs in the fields of molecular genetics, cell physiology, biochemistry and biochemical engineering. With new and powerful tools such as genetic engineering, cell culture, plant regeneration, hybridization of organ and tissue cells, embryo storage and transfer and the controlled production of specific antibodies, scientists are beginning to harness the diverse and virtually unlimited capacity of natural systems to produce goods and services of benefit to man.

In agriculture and the chemical and pharmaceutical industries, biotechnology already is producing dramatic results. Improved plant species that can mean increased yields, disease resistance and more efficient harvesting are being developed and tested. The market for genetically-improved plant seeds may reach $8 million in 1985 and $7 billion by the turn of the century. The cancer-fighting drug Interferon, formerly valued at $10 billion per pound, is now produced using biotechnological processes so efficient and inexpensive that researchers can obtain free samples. The cost of cancer treatment with Interferon has correspondingly dropped from $1,000 a day to $30 a day.

Biotechnology using marine organisms and systems is in its infancy compared to its application to terrestrial plants and animals. Biotechnology requires fundamental knowledge about genetics, physiology, biochemistry and bioengineering; however, for marine organisms, this knowledge is largely undiscovered. Similarly, little attention has been given to developing and adapting the tools of biotechnology for the unique requirements of marine systems. Support for biotechnology research and development has focused primarily on terrestrial organisms. For example, in 1983 an estimated $55 million was directed to biotechnology research in agriculture via the state Agricultural Experiment Stations of the Land Grant colleges, and the U.S. Department of Agriculture's Agriculture Research Service. During roughly the same period, Sea Grant support for marine biotechnology research, federal and non-federal funds combined, was less than $8 million.

Much of the current research in marine biotechnology seeks a basic understanding of marine organisms and biological systems associated with persistent marine problems. Areas of research include the biological and biochemical processes of marine biofouling; the metabolic pathways which produce the chemical structure of marine toxins; the isolation, identification and physiology of human pathogens of marine origin; and the understanding of the structure and function of genes in marine plants and animals. Research is underway to identify pharmaceutical and chemical products that may be produced through biotechnology.

Another aspect of marine biotechnology research is the development of techniques for implanting in marine organisms genes which produce certain desirable characteristics. Finally, biotechnology is enhancing ongoing marine research. Applications include the following: Producing and using monoclonal antibodies to detect and diagnose fish diseases caused by marine microbes; developing vaccines for treatment of fish diseases; identifying and producing bacteria which can break down waste products in the marine environment; determining the origins and structure of fish populations; and increasing production of aquacultural systems.

The Challenges Facing Marine Biotechnology

The potential benefits of advances in marine biotechnology are immense. For example, the U.S. seafood industry currently is faced with an annual trade deficit of more than $3 billion and the

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Researchers at the University of Maryland, Baltimore County, examine an autoradiogram showing the DNA sequence of a plant chromosome.

production of large quantities of waste. Biotechnology can help change these unsatisfactory situations through improvements in fish production, fisheries management and commerical use of wastes. Also, biotechnologically-enhanced aquaculture can create new or alternative job opportunities and sources of food products for the commercial fishing industry.

The marine sector's contribution to the national economy can be dramatically improved as new products, including pharmaceuticals and specialized chemicals, are developed from marine organisms. The U.S. Office of Technology Assessment has estimated that before the year 2000 annual sales of chemicals and drugs produced through biotechnology will reach $15 billion. Marine biotechnology can make a significant contribution to realizing this prediction.

Biotechnology holds promise for solving the problems of disposal of industrial and domestic waste in the marine environment. Genetically engineering marine microbes so they can detoxify wastes or produce useful compounds from them is an avenue of particular promise.

Marine biotechnology offers the United States the opportunity for international leadership. Developed countries throughout the world are making major commitments to the development of biotechnology, but a concerted effort in marine biotechnology has not been mounted. Our nation's competitive advantage in biotechnology can be enhanced by seizing this opportunity.

Current Sea Grant Research Program

Sea Grant is a major source of support for academic research in marine biotechnology. For example, it is the primary national sponsor of research in marine pharmacology and aquaculture. Current Sea Grant research directed to biotechnological development addresses biochemistry, pharmacology, genetic engineering, biochemical engineering, microbiology and botany, in addition to aquaculture. This research program and some of its recent achievements are discussed here.

Biochemistry and Pharmacology

This research examines marine organisms to see if they contain substances that can be used to produce pharmaceuticals. The chemical structures of approximately 40 new compounds from marine organisms have been determined over the past two years.

Working together, researchers at the University of Hawaii and Cornell University have found that halenaquinone, a substance isolated from a sponge, is an antibiotic, and represents a new chemical structural system. At the University of California, three new compounds were isolated and shown to inhibit tissue inflammation at medically significant levels. Two of the compounds also are analgesic and one inhibits sperm motility and cell division. Inhibition of cell division is indicative of ability to stop growth of tumors. Also, scientists at the University of Oklahoma isolated two potential anticancer drugs of high specific activity from sponges. Both drugs are being tested further at the National Cancer Institute.

Scientists at the Massachusetts Institute of Technology (MIT) isolated another substance, not completely characterized, from shark cartilage. It was shown to strongly inhibit the growth of new blood vessels in artifically introduced solid tumors in rabbits, thereby restricting tumor growth. The substance is expected to be applicable in other kinds of antitumor studies. Pharmaceutical firms are expected to secure rights to these discoveries for further investigation and possible commercial development. Several major firms already are contributing funds to several academic projects and providing their services in biological evaluation of new substances.

Researchers at the Universities of Washington and California (Berkeley) and the California Department of Fish and Game are working together to further perfect the ability to predict migratory readiness of salmon by determining the biochemical processes involved with migratory behavior growth. The studies so far indicate that subtle environmental changes may be the key to priming of the thyroid gland that controls physiological changes required for succesful downstream migration and entry to and growth in the ocean.

The U.S. researchers are working collaboratively with researchers in France and Japan. The results of these basic studies, which were the highlight of an international meeting on salmon reproduction held in Seattle in October 1983, are expected to provide the basis for much better management of salmon and greatly increased efficiency in hatcheries.

Genetic Engineering

Genetic engineering is the manipulation of the genetic makeup of organisms. It can be used, among other things, to produce a useful reagent, to control diseases of marine organisms, and to enhance the growth and hardiness of aquacultured species. For example, researchers at the University of Hawaii are developing monoclonal antibodies to ciguatoxin through cell-fusion techniques. Ciguatoxin is the natural substance, transmitted through the food chain to tropical finfish, which causes the disease *ciguatera*, a neural disorder, in humans. It is a significant problem in Hawaii, Puerto Rico, Florida and many other locations where tropical fish species are eaten. If antibodies to ciguatoxin could be produced, they would hasten development of a rapid test of fish with commercial potential, and would allow greater development of fisheries.

Researchers at the University of California, Santa Barbara, have shown that application of insulin and growth hormone accelerates growth in abalone by improving metabolism. On the basis of these findings, they are working to establish recombinant DNA gene banks from molluscan species. These gene banks will be used to identify, select and increase production of genes that produce desirable characteristics, such as disease resistance. This would allow production of strains of abalone with enhanced growth rates, disease resistance, and the ability to synthesize protein and glycogen. The techniques developed would be applicable to other species as well and would significantly advance the science of marine animal husbandry.

Scientists at Johns Hopkins University are learning to manipulate genes and proteins of striped bass which control their resistance to heavy metal pollutants. This research is expected to produce methods useful in genetically improving finfish of all types.

Infectious diseases cause enormous losses of salmonid species in hatcheries and other aquacultural facilities. Researchers with the Oregon, Washington and Maine/New Hampshire Sea Grant College Programs are applying recombinant DNA technology to produce vaccines and diagnostic agents. Their approach is based on determining the fundamental chemical and physiological ways that bacteria and viruses invade and infect the host fish.

Biochemical Engineering

This field of study involves the production of materials or development of processes potentially useful in industry. Researchers at MIT are developing applications for the polymer chitosan, which is derived from the shells of edible crustaceans. In some places, especially Virginia, Alaska and Texas, shells left after processing constitute an enormous waste management problem. Chitosan appears to have good potential for bioproduction or fermentation processes, and research at MIT will provide more information about chitosan's properties.

Research is underway at Cornell University to develop the technology to extract and recover oils and enzymes from fish and other marine organisms. Several fish oils have specific nutritional and potential therapeutic properties, and a number of enzymes from fish are of commercial interest. Traditional methods of extraction and recovery of materials of this type involve application of heat, which denatures protein and destroys enzymic activity. Use of gases, such as carbon dioxide, at certain temperatures and pressures produces fluids that are highly effective solvents. The solvents can be removed through chemically gentle reconversion to the gaseous phase without heating. Use of this technology to isolate biochemicals should present opportunities for expansion of marine commerce by creating new uses of fishery resources.

Microbiology and Botany

Researchers are pursuing specific problems and opportunities, including developing food crops from marine plants, controlling marine fouling and paralytic shellfish poisoning, using chitosan as an agricultural fungicide, and defining the effects of nitrogen metabolism on the chemical composition of macroalgae.

In research aimed at preventing biofouling, for example, investigators at Harvard University have developed a theoretical model of biofouling. The model indicates that the first step in attachment is a reaction between compounds produced by natural bacterial films in seawater and the larvae of biofouling organisms. Their studies so far suggest there may be ways of disrupting this early attachment process.

At the University of South Alabama, Sea Grant scientists have focused their attention on prevention of mineral scaling and biomineral fouling of marine surfaces, costly problems for industry and the military. Sales of antiscalants alone, whose environmental consequences are not fully defined, total several hundreds of millions of dollars annually in the U.S. The research is based on the surprising observation made in 1981 that the organic matrix in oyster shell is a potent inhibitor, rather than an initiator, of growth of crystalline calcium carbonate ($CaCO_3$). The scientists have shown that synthetic substances modeled after the matrix, and matrices of other marine organisms, also inhibit calcium carbonate growth. These observations and studies raise the potential for developing methods to prevent calcium carbonate fouling using fundamental natural processes.

Other current research in this area includes applying modern techniques to improve salt-tolerant plants for human and animal food and other improvements in agriculture. Highly significant advancements have been made in this field recently at Washington State University. Plant pathologists there have determined that the marine polymer chitosan, derived from crustacean shellfish wastes, is effective in protecting pea seedlings and other crops against pathogenic fungi of the genus *Fusarium*. More importantly, their recent studies have shown that inexpensive treatment of wheat seeds with chitosan will increase yields up to a remarkable 20 percent.

Fields studies of this treatment method are continuing on 320 acres in eastern Washington and six acres in Oklahoma. The researchers will attempt to define the mechanism of chitosan's action. Apparently, chemical subunits of chitosan selectively activate genes which are an essential part of the plant's ability to resist disease. Once the way in which chitosan activates specific plant genes has been determined, it may be possible to expand the use of chitosan and its derivatives to other plant disease problems.

Knowledge of the mechanisms by which synthetic compounds affect gene expression also has far-reaching implications in the development of new pharmaceuticals and the treatment of human diseases.

Research Needs and Opportunities

On-going Sea Grant-supported research is addressing novel opportunities and difficult problems whose exploitation or solution will improve the economic posture of the U.S. Its results may include such things as new industrial and agricultural materials; streamlining and simplification of fermentation processes using novel biochemical techniques; increased yields of carrageenan from genetically-improved algae; and use of shark cartilage extract for the treatment of cancers.

An increased level of research effort is essential if progress in marine biotechnology is to continue. Current funding is not sufficient to take advantage of the exciting opportunities which are arising. Examples include the production of marine biomass as raw material for generating energy and chemicals, and the development of novel industrial chemicals and processes from marine bacteria which live in hydrothermal vents in the seafloor and can metabolize hydrogen sulfide, a toxic industrial product.

In marine biotechnology, as in other fields of biotechnology, basic research is particularly needed to determine the structure, function and expression of the genes of plants, animals and microbes. Opportunities for significant commercial application through expanded marine biotechnology are possible in fields including the following:

- Fisheries Enhancement, Management and Protection
- Industrial Materials and Specialty Compounds
- Pharmaceuticals and Enzymes
- Management of Wastes in the Marine Environment
- Environmental Health
- Methods Development and Improvement
- Aquaculture of Plants and Animals

Congress established the National Sea Grant Program in 1966 to accelerate the development, use and conservation of the Nation's marine resources. During its nearly 20 year history Sea Grant has forged an effective partnership with universities, marine industries and governments. The research skills of university scientists from all fields — oceanography, engineering, law, economics, sociology — are combined with a strong commitment to make research findings available to a wide audience through a network of advisory and education specialists. Technical, advisory and public information reports, conferences, workshops and personal contacts by Sea Grant marine agents and university researchers ensure that information needed to use and develop marine resources reaches those who need it.

This experience, coupled with the partnership nature of the program, gives Sea Grant a unique perspective on current and future national needs in marine resource development. This paper is one of a series, each describing an issue of national importance, Sea Grant's contribution to tackling that problem, and priorities for future research.

Ms. **Mikulski**. Mr. Embry, do you have a statement? Can you share with us how we came to this point?

STATEMENT OF BOB EMBRY

Mr. **Embry**. My credentials include no scientific background other than freshman chemistry in high school, which I didn't do too well on, but I do have some background with Baltimore and with the problem of cities.

This facility, the aquarium, was conceived to serve two purposes. One was a tourist attraction, and the attraction has been two or three times greater than projected.

That has certainly worked. Second, it was to copy something Congressmen Shumway alluded to in California, the tremendous success San Diego has had in encouraging ocean-related research.

Baltimore, like Seattle, and many other urban communities in this country, suffers inordinately from unemployment, deteriorating tax base and many other problems.

The subject matter of your hearing presents a coincidence of interest that is rare, that is the national interest in remaining competitive and the need for pure scientific to learn as much as we can about our world and improve our life, a universal desire. We find ourselves in a unique competitive position with the rest of the world; and as we approach the end of this century, we find ourselves losing many competitive battles with some of the other countries, particularly Japan, so there is a great need to encourage research in these areas.

How it should be done comes down to national planning, what role the National Government should take in trying to make us more competitive. I assume everyone would agree that to the extent the Federal Government can encourage research in these areas without becoming overly restrictive and interfering unduly in the private market, it should do so, The interest is not just national interest there is also a local interest in encouraging this type of research and job-created activity is the areas of highest need.

Baltimore built this facility largely with Baltimore's funds. There was a small EDA grant, maybe representing 5 percent. Everything that you will see has some Federal participation in it.

The view from this room would not be possible without the Federal Government, either through urban renewal, 202, Action grant, or a variety of other programs. The city of Baltimore has demonstrated a scandal-free, efficient use of Federal money, and the leverage Federal funds can produce is the fact that $1 of Federal money has produced $7, $8, $10 of private money, so it has been a very wise investment. But we have to expand our horizons, not just through building hotels, housing, and marketplaces, all of which are very beneficial, but by trying to tie the smokestack cities and the laboratory development that is taking place Bethlehem Steel, Western Electric, and other heavy industry facilities in Baltimore experience ups and downs.

It is important that we tie Baltimore and other cities like it into this new area of development, so new jobs that are being created can be shared with people who have been shut out.

I know there is an argument about the free marketing being restrained by such interference. Japan, often cited as the model of for research and development, is also a model for encouraging development to take place in more distressed parts of Japan.

Eric Vogel's recent book, "Comeback," which indicates a number of varieties of case studies, points out how Japan is intervening in the market, where unemployment is the highest, economic development has to take place.

There is no inconsistency in competing in international level and making sure all citizens benefit equally.

Ms. **Mikulski.** Mr. Berkowitz?

STATEMENT OF BERNARD BERKOWITZ

Mr. **Berkowitz.** I have prepared written testimony that I would like to have entered into the record.

Ms. **Mikulski.** With unanimous consent, the committee would so enter it.

Mr. **Berkowitz.** I thought it would be very important for this subcommittee to be aware of the priority that Baltimore City has given to biotechnology as a target area of economic development.

We see biotechnology, not only as a growth area nationally and internationally, with regard to economic development, but as one where Baltimore City and the State of Maryland have some special and important advantages, locational advantages.

In fields like biotechnology, technology-based fields, that the presence of research institutions acts as not only an important attraction for economic development, but also spawns a good bit of economic development, as the academic researchers often become entrepreneurs and develop their own companies.

In Baltimore, we are fortunate in having two outstanding medical institutions: the Johns Hopkins Medical Institution, and the University of Maryland Medical School and Hospital.

We also have this aquarium, which is a very special facility of importance to marine biology. Elsewhere in the State, in the Washington, DC area, is the National Institutes of Health, so there is an aggregation of research capability, of intellectual talent on a world-class level, and one we need to capitalize on for our own economic development as other areas have.

Some important steps have been taken to capitalize on these resources. Dr. Colwell has put forth one of the most imaginative initiatives in our State, and has proposed an Institute of Biotechnology at the University of Maryland, and that institute would have several locations in the State, including a location in Rockville, where there is an advanced biotechnology center under construction.

There would also be two centers here in Baltimore, a marine biology center and a biomedical center, and recognizing the resource the aquarium is in the field of marine biology and the resource that the medical institutions are here in the field of biomedicine.

We are in the process of acquising a building in the vicinity of the University of Maryland which will house at least the biomedical center and possibly also the marine biology center, but in any case, those two components are committed to be located in Baltimore, and there is a close cooperation between the city administration, my organization, the Baltimore Economic Development Corp. and the University of Maryland, in developing that facility, which will be a generator of economic activity.

We are also working in a partnership with the Johns Hopkins Medical Institutions. They now own the former City Hospital property, now called the Francis Scott Key Medical Center, and we are in a partnership with them developing land at that facility as a biomedical business park.

The first biotechnology company located there last summer in a formerly vacant building, and again, the project represents a kind of partnership of the sort that Mr. Embry talked about.

The money used to renovate the facility was EDA jobs funds that Congress approved in 1983, and the city renovated the building and leased it to Nova Pharmaceuticals, a new company that is growing quite rapidly.

We have committed several million dollars for the development of infrastructure at that biomedical park, and several million dollars for developing the Baltimore components of the Institute of Biotechnology.

Congresswoman Mikulski pointed to the Inner Harbor as an example of Mayor Schaefer believing in turning a lemon into lemonade, and that was not produced without considerable assistance from the Federal Government, and in fact, it was not produced without a real partnership of the city, the State, the Federal Government, and the private sector.

I believe that the same kind of partnership is required in the field of biotechnology at the local level, as well as other levels of government in the United States, if we are going to capitalize on our opportunities in this important growth field.

We already have important elements of a partnership in place, I believe, between the city and the universities, between the city and the State.

We badly need the Federal Government to be a partner in this activity also and to support the development of major research facilities like the Institute of Biotechnology not only here, but in other parts of the country.

The venture capitalists that have funded Nova Pharmaceuticals are the same ones that funded Genetic Systems, a company in Congressman Miller's section of the country, in Seattle.

I think there are benefits certainly to all of the Congress people represented here today in the development of biotechnology, and it does need support from all levels of government.

Thank you.

[The statement of Mr. Berkowitz follows:]

STATEMENT OF BERNARD L. BERKOWITZ, PRESIDENT, BALTIMORE ECONOMIC DEVELOPMENT CORP. [BEDCO]

As the United States as a whole and metropolitan areas like Baltimore continue to experience the difficult problems of declining employment in the older manufacturing industries, creating and attracting new sources of employment in the growth sectors becomes more critical to the economy of the Nation and its cities. That is why Congresswoman Mikulski and the subcommittee are to be commended for this hearing about marine biotechnology and its business and job development potential.

We in Baltimore have targetted biotechnology, including, of course, marine biotechnology, as a priority growth industry. This decision was based on the rapid growth occuring in biotechnology and its commercial applications and especially on the world class biotechnology research talent in Baltimore at our Johns Hopkins University and at the University of Maryland. In the marine biology field, we also view Baltimore's national aquarium as an important resource.

Partnerships have been established with Hopkins and the University of Maryland to further biotechnology research and business development. Through BEDCO, the city will soon acquire a building at the University of Maryland's downtown Baltimore professional campus which will house the biomedical and possibly the marine biology components of the university's institute of biotechnology, both components being committed by the university to Baltimore locations. The Johns Hopkins University and Baltimore City are partners in developing a biomedical research and business park at the Francis Scott Key Medical Center Owned by a Hopkins subsidiary. The first new biotech firm located there last year.

The priority Baltimore attaches to biotechnology business development is indicated by several million dollars of bond funds allocated to carry out these projects.

Just as the city and the universities have recognized the economic growth potential of biotechnology, I would urge a similar recognition and support by the Federal Government. Support at all levels of government is important to assure a continued lead position for the United States in this important field.

Ms. MIKULSKI. Thank you, and I would like to introduce my colleague from Washington, Congressman Michael Lowry, who has joined our committee.

Dr. Colwell, I have a few questions for you relating to this issue of the role of the Federal Government. We hear what you and your intellectual counterparts around the country are doing.

Would you share with the committee what role the Federal Government is playing in this, and what role you think the Federal Government should play, if any at all? How much are we spending on research?

Is the Tax Code a help or a hindrance?

Dr. COLWELL. Thank you. I can speak from several perspectives, as a grantee of the National Science Foundation, and as an active researcher in the Sea Grant College Program.

Most of the funding for marine biotechnology comes from the Federal Government through the National Sea Grant College Program. The Federal Government is spending about $8 million for marine biotechnology, most of that is the National Sea Grant College.

Ms. MIKULSKI. Is that for the University of Maryland?

Dr. COLWELL. No, that is the entire country, all of the effort in Marine biotechnology. It is quite equitably distributed, but it is a very small sum of money compared to the investment being made in marine biotechnology by other by other countries, including Japan and the European countries.

The role of the Federal Government should be to supporting basic research in marine biotechnology. Basic research is badly needed. Terrestrial or medical biotechnology cannot be applied to marine biotechnology without linkage to marine biology chemistry and physiology.

Marine systems, such as those organisms growing under several hundreds of atmospheres of hydrostatic pressures, need to be studied using special equipment. Although the fundamental techniques are the same, and even though very rapid steps forward can be made using current medical procedures, marine biotechnology requires a unique interdisciplinary combination of engineering, marine biology, and marine technology, as well as molecular biology and genetic engineering.

Such an interdisciplinary program is now being put together at the University of Maryland in the Center of Marine Biotechnology, one of the four centers of the Maryland Biotechnology Institute. The Governor of the State of Maryland has provided approximately $1.3 million for the Center of Marine Biotechnology. Maryland has joined together the University, industry, Baltimore City, and the National Aquarium. All are important parts of the linkages of resources in the State of Maryland.

Ms. **Mikulski**. Now the Federal Government is involved in a variety of activities in biotechnology, marine biotechnology being one component, is there a national clearinghouse that is a one-stop shop that says what is going on in marine biotechnology and, who is doing it?

Dr. **Colwell**. There is no clearinghouse for marine biotechnology at the present time except for the National Sea Grant College Program. The OTA has done an assessment of all of biotechnology in the United States and a Cabinet-level working group in biotechnology has been formed but no study of marine biotechnology has been done at the Federal level, except, as I noted, the National Sea Grant College Program of NOAA.

There should be a clearinghouse, because there are clues in the literature, as to which organisms may yield pharmacologically active substances that can be extracted and developed using marine biotechnology methods.

For example, titanium and other strategic elements could be extracted using the tools of biotechnology, from the sea. The United States can be in the forefront in marine biotechnology . . . and should be. The amount of funding for marine biotechnology is abysmal, frighteningly small compared to other countries.

Ms. **Mikulski**. Mr. Berkowitz or Mr. Embry, in this major capital investment at the local level, what economic benefits do you hope to achieve in one State from this consortium of endeavors?

Mr. **Berkowitz**. We hope to achieve growth in jobs and growth in the local tax base, and not only growth in research and development jobs. As the products are perfected, by the biotechnology companies, experience has indicated that the tendency would be for the initial manufacturing plants to be located close to the research facilities.

Ms. **Mikulski**. So, this would be what Silicon Valley was to California. This would be a new opportunity?

Mr. **Berkowitz**. Biotechnology Valley.

Ms. **Mikulski**. I have lots of questions, but I will recognize my colleagues.

Mr. Shumway.

Mr. **Shumway**. Dr. Colwell, I have a question that may pertain to the state of this science many years down the road, but nevertheless, it is the kind of thing we should be looking at now and planning for.

You mentioned that the estimated value of genetically manipulated seeds for plants is presently about $8 million, and yet, you project it to be $7 billion by the year 2000.

I am concerned about the transition between what is now going on and what eventually may be in the hands of private enterprise. Now, much of the research is being funded through public sources and you have stressed how important it is for the Federal Government to stay involved.

How do we bridge the gap from this federally funded, federally manipulated, if you forgive the use of that word, research and development into, I am sure that by the time these seeds become a reality, private enterprise which will be in the picture and reaping much of the profit from that great increase in value.

Dr. **Colwell**. Agriculture provides the perfect example. We have had approximately 100 years of applied research in agriculture, and we know a great deal about plant breeding. Seed development has already been put into the private sector.

Monsanto has invested $150 million in their new plant biotechnology facility in St. Louis, which is linked with Washington University. They are working on insertion of genes for insecticide resistance and/or herbicide resistance into plants, as well as resistance to disease, among the projects underway.

They are already in the process of carrying these new plants to the market. If we can have the same kind of investment, that has gone into agriculture over the past 100 years, in marine biotechnology, we would be in the forefront of economic development within a decade. Thus, we have a catch-up to do to exploit marine biotechnology bring it into the private sector.

Mr. **Shumway**. Is Monsanto then going to be the recipient of a windfall benefit, great research having been funded by the Federal Government, placed in their laps now, capable of making a handsome profit in the private sector?

Dr. **Colwell**. I think the people of the United States are the beneficiaries. Monsanto is but one example. There are large numbers of biotechnology companies that have been established in California, the Midwest, the mid-Atlantic and the gulf coast, and in each State, the emphasis in biotechnology in each State emphasizes that which is appropriate for the State.

For example, Michigan is focusing on forest products. In Washington State, a good deal of research is being done on aquaculture, and on bioelectronics in the New England area, and in all these States, as in Maryland, where the richness of the Chesapeake Bay is available, the beneficiaries of the Federal research funding will be the people who will have the new drugs and the new opportunities to exploit.

Mr. **Shumway**. With that kind of heavy reliance upon Federal or public funding sources, is that any kind of a deterrent to the private sector to provide money for its own research and development, perhaps provide grants to schools like yours?

Dr. **Colwell**. The Federal funding serves as a catalyst, a very important catalyst. In the case of the National Sea Grant College Program, matching funds are required and have readily been provided by the States. Connections with industry have been made and the response has been extraordinary. New products have been developed in fisheries and these successes have been documented, and the information provided, by the National Sea Grant College Program network.

The National Sea Grant College Program is a fine example of the beneficial effect of a relatively small sum of Federal money. It has been leveraged up to tenfold, a hundredfold and even a thousandfold. We are seeking to work together in marine biotechnology to put industry, the Federal Government, the university, and the State and local governments into a working partnership. This is what we have done in the State of Maryland, in forming the Center for Advanced Research in Marine Biology, and the Center of Marine Biotechnology. An important component in each center is industry.

The local, State and Federal governments, the university, and industry are linked, with the university the source of the basic research and development.

Mr. SHUMWAY. With reference to Sea Grant, and I know you are a participant in that program, given the importance of marine biotechnology in the scientific field today, do you see any higher use of Sea Grant funds in the various States than application toward marine technology?

I know there are laboratories existing that need this funding, but those areas that are contemplating moving out into new areas, is there any area that has higher priority than this one?

Dr. COLWELL. An investment in marine resources must be made by the Federal Government. I mentioned bioelectronics, biochip, and biosensors is a critical area that has been neglected.

A report for the National Academy of Science, biotechnology applied to U.S. naval needs, has been completed recently. In that report are listed some areas in marine biotechnology and marine resources vital to the U.S. Navy.

Clearly, the nations of the Earth must turn to the sea. The sea is a major source of food for all mankind, but marine biotechnology will bring to pass the exploitation and protection of the marine resources.

Mr. SHUMWAY. One more question, if I might?

I think it is apparent that there are from time to time some gaps between pure scientific endeavors such as Dr. Colwell has described to us, and the free market system that those in the business world espouse and hold as an ideal in this country.

I am curious about bringing the difference between science and business in that regard, do you see any kind of institutional blockades that might now stand in the way of this kind of scientific research or regulatory hindrances to the kind of research described by Dr. Colwell?

Mr. BERKOWITZ. I am not familiar enough with the regulatory aspects to comment on that side, but it seems to me that there is an analogy between the governmental-private relationship to the university-private relationship.

The universities have been struggling with the problems of the transfer of information and knowledge gained as a result of their academic research to the private sector, and I think that they are coming to pragmatic solutions to those problems, and the same thing will have to be done between the Federal Government and the private sector, and those solutions appear to be through some kind of sharing in the benefits, sharing in the revenues, that revenue stream that will result from those discoveries.

Mr. **Embry**. I think your questions touch on a much more vital issue than any scientific question, the relationship of Government to private industry in the next few years. We have an adversarial relationship that has been built up in our view of whether one company benefits over another in our domestic economy, and that is oftentimes the initial reaction, corruption, favoritism, all very important questions, but they are more relevant to the 19th century than to the 20th, in that looking at our domestic market rather than a worldwide market, we should be looking at the major Japanese or French or English company, where they are creating a product that beats us out in some markets around the world.

Who benefits from Monsanto's development of a particular technology? The American people. That is the overwhelming answer, and there are many roadblocks existing between, a traditionalist, a liberal, a liberal view of Government as favoring the wealthy and therefore, in the Democratic Party, there has been a hostility between this kind of partnership and has to be overcome, because it holds back our economy and our country.

The antitrust laws and the marketing restrictions, and so forth, are all framed on a basic philosophy of Government that is outdated.

Dr. **Colwell**. A comment can be made from another perspective. There are bioethical questions to consider in biotechnology. The University of Maryland, part of the Maryland Institute of Biotechnology, has established a Center for Bioethics, dealing with the societal issues associated with biotechnology.

The other point to be made concerns the release of genetically engineered organisms to the environment. It is, of course, a very important question. As president of the American Society for Microbiology, I am pleased to report that this issue is being dealt with on a scientific basis. It is a very important issue that Congress will have to decide.

How the issue is dealt with can make or break the future of the United States in biotechnology.

Mr. **Shumway**. Thank you, Madam Chairwoman.

Ms. **Mikulski**. I would like to remind the committee of a couple of things. One, this is the first of a series of hearings in marine biotechnology. Today's hearing is meant to be marine biotechnology 101, an introduction to the concept.

Some of these issues that we are raising—whether they are on the governmental role in the use of funding of basic research, tax codes, funding the venture capital, issue of regulations, should or should it not be, the R&D tax credit, how we stimulate the private sector—are all part of it, and I anticipate a separate hearing with some of our colleagues on these tax issues.

We will be hearing regulations later on.

Congressman Lowry.

STATEMENT OF HON. MIKE LOWRY, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF WASHINGTON

Mr. **Lowry**. Thank you for your leadership on this issue. I am really glad to see the potential for us getting back into the lead as to where we can be competitive, not be looking at protectionism, yet providing jobs, so I like the attitude being expressed here.

Dr. Colwell, if I heard your answer correctly, you said there is approximately $8 million in Federal dollars annually invested. You talked about a Federal responsibility of supporting basic research.

What type of future annual dollars do you see a Federal responsibility of providing basic research to be, as a general figure?

Dr. Colwell. Looking at the overall Federal budget, which includes approximately $1.5 billion for the National Science Foundation, very little if any of that goes into marine biotechnology. Looking at the $8 million spent in the National Sea Grant College Program, I would strongly recommend that that program be expanded to two or three times, even 10 times that amount of money to ensure the success of marine biotechnology for the United States.

That is, in addition to core funding for the National Sea Grant College Program, there should be $16 to $24 million for marine biotechnology added to the National Sea Grant College Program. That would put us in a leadership position.

Mr. Lowry. $16 to $24 million?

Dr. Colwell. $16 to $24 million added to the National Sea Grant College Program.

Mr. Lowry. That is a very good answer and a small amount of money to provide. In case of cattle feed, we found out that feed supplements to get fatter cattle and faster growth rates produced cancerous type results.

Who is regulating these types of scientific advances out in the market?

Dr. Colwell. Many agents are involved in advising on regulations, including FDA, EPA, and USDA. In fact, the regulations proposed for release of genetically engineered organisms represent input from all of the Federal agencies, including EPA, FDA, USDA, NIH, NSF, all have had input.

Mr. Lowry. Is the regulation going to do any good? I don't happen to be a person that thinks the only objective is to get something out into the market and have some very disastrous results 12 years later, when you are having kids.

Is the regulation working?

Dr. Colwell. There is something important and fundamental that must be understood. The products that are coming out from genetic engineering should be regulated no differently than products already are being regulated as food or drugs now.

The process should not be regulated. It is the product and its use that must be examined. We have been releasing organisms to the environment for years. In fact, every sewage discharge releases billions and billions of bacteria and viruses to the environment. In the case of agriculture, microorganisms forming nodules on the roots of plants have been added to soil to increase the fixation of nitrogen.

That application has been practiced for decades. It is not new. The spectres that have been raised regarding genetically engineered organisms are conjectural. Nevertheless, let us be wise, let us be sensible, and let us learn from the past and make sure we don't create problems but also, don't create problems that do not exist.

Mr. Lowry. Thank you.

Ms. Mikulski. Mr. Miller.

Mr. Miller. Moving along with our science 101 course here, you talked about the importance of the Federal role, Dr. Colwell, in basic research, and I am trying to come up with a layman's explanation of basic research versus other kinds of research.

You mentioned agriculture, for example. My impression is that the U.S. Government, the Federal Government, has funded a lot more than basic research in the field of agriculture, so how would you help us draw this line here in this field of marine biotechnology?

Dr. Colwell. Well, that is a very good question. Scientists have argued endlessly about what is basic research and what is applied research.

Let me offer the following. What we need to do right now is to expand our fundamental knowledge of the genetics of marine organisms, the fundamental knowledge of genetic manipulation and bio-processes for production of the value and interesting compounds from the sea so that we can utilize them for the benefit of humankind.

We should not expect immediate products. We must allow time to understand the fundamental genetics of marine systems. We have had the benefit of decades of applied genetic research in agriculture, but not in marine biology or marine biotechnology.

A definition of basic research implies studying to advance knowledge. Yet, we must be pragmatic, and marine biotechnology offers the opportunity for basic and applied research.

Mr. Miller. I see the necessary contradiction here. On the one hand, nobody at the Federal level wants to appropriate money for which there is no apparent return. Yet, by definition, that is precisely what you are suggesting, and I agree with you, that is what the Federal role should be here.

Dr. Colwell. Yes, the position taken here is that the bets can be covered. For example, in Japan, products of marine biotechnology are either near to marketing or already marketed.

Extracts of marine sponges appear to be active against leukemia and, obviously, should be explored farther.

The fundamental research is necessary to exploit fully the potential of marine biotechnology.

Mr. Miller. One last quick question. Obviously, from a point of view of a city like Baltimore in terms of what consistency we are going to give, you are not looking at it in terms of basic versus applied research.

I assume one of your criteria related to jobs. Could you elaborate on how you applied this criteria and what results you found as a city looking at this potential, science and industry?

Mr. Berkowitz. The assistance that we would provide would be in two forms. It would be expenditures for infrastructure for the development of streets, utilities, landscaping, et cetera, in connection with developing the biomedical business park in conjunction with Hopkins and in connection with the University of Maryland, it would involve an expenditure for the acquisition of property, improvement of property for the housing of the components of the Institute of Biotechnology.

pages tightly bound

We see the creation of both of these centers of research as being important, because they are important in attracting, in a sense, marketing our area for biotechnology and also, the creation of sites and buildings where biotechnology firms can locate in a convenient, economical fashion, which is important in engendering this kind of development.

All of this is based on our judgment, correct, I hope, that there is considerable potential for both job development and tax-base development in this field, and it is based on the projections that are being made for the growth of the biotechnology industry.

Mr. **Miller**. You had specific projections that you were making your decisions based upon.

Mr. **Berkowitz**. Yes, sir.

Ms. **Mikulski**. The point is that local government provides the architectural test tube for biotechnology. You provide an aquarium, using a two-pronged approach, tourist attraction, research within an architectural framework, and land acquisition. But the question becomes, who pays for what will go on?

Certainly, there should always be a partnership between the Government and the private sector. We hosted a meeting with the House of Lords in England. All of their research goes on only through Government institutions, their national institutes.

What they were so dazzled with when they visited the United States, is that the United States of America has confidence in private sector institutions. In addition to our own institutions, like the NIH, we fund American universities.

Our knowledge, therefore, belongs to the world, not to an individual company or university. As I recall from that meeting, it was something that they liked, because it encouraged more entrepreneurship, rather than bureaucracy.

You have given us a picture of what is a very good beginning to this, and we thank you for your testimony. We hope, as this hearing progresses, we will get an idea what the industry is doing, where we are in the international market and research place and some of the regulatory issues.

Also, we will be having a lunch where the committee members will be able to interact with the other witnesses.

We would now like to call these private sector people who are using and applying some of these activities: Baltimore Gas & Electric, Louisiana State University, and a private firm from the State of Washington. We would like to thank the witnesses for coming. We want to thank Baltimore Gas & Electric, and we know the president would have liked to be here. Mr. Chris Poindexter, thank you for coming. We would love to know how a major utility is now involved in biotechnology.

STATEMENTS OF CHRIS POINDEXTER, VICE PRESIDENT, BALTIMORE GAS & ELECTRIC, ACCOMPANIED BY DR. JOHN KRAEUTER; DR. RALPH PORTIER, LOUISIANA STATE UNIVERSITY; AND DR. ARTHUR KARUNA-KARAN, PRESIDENT, CYANOTECH CORP., WOODINVILLE, WA

Mr. **Poindexter**. Madam Chairman, thank you very much.

My name is Chris Poindexter, and I am vice president of engineering and construction for the Baltimore Gas & Electric Co.

We are grateful for being here. I would like to introduce you to Dr. John Kraeuter, the supervisor of our aqua facility and in the audience Dr. Bauereis, acting director of environmental programs.

Four years ago, our chairman of the board, Mr. Bernard C. Trueschler, challenged me to come up with a design for an aquaculture facility. We would like to brief you on our activity and share with you some thoughts on how aquaculture and biotechnology may be able to contribute to our region's and our country's increasingly important seafood industry.

Why is an investor-owned utility company interested in the operation of an aquaculture facility? Simply stated, as the area goes, so goes our company. Our welfare is closely linked to the well-being of the area we serve. Central Maryland's economic strength, natural beauty and resources and quality of life are all important factors which concern us. The Chesapeake Bay is clearly the area's most prized natural resource. Our concern is reflected in our involvement in varied activities which have the common goal of improving the overall condition of the Chesapeake Bay. Our chairman of the board is a member of the Governor's Chesapeake Bay Oversight Commission. The director of our environmental programs started a new 1-year assignment July 1 to head up Maryland's new Chesapeake Bay Trust. Dr. Kraeuter, Dr. Bauereis, and their colleagues are on many, many advisory committees to both governmental agencies and organizations involved with improving the quality of the bay and its marine life. We have commissioned the Estuarine Federation and the Philadelphia Academy of Natural Sciences to publish 13 years of scientific data collected in the vicinity of our Calvert Cliffs nuclear powerplant. This will be the largest compendium of peer-reviewed scientific data ever assembled for one area of the bay.

But what we came here to talk about today is our aquaculture facility. It is located at our Charles P. Crane Plant on Seneca Creek in Baltimore County. Four years ago when we began to investigate what was a reasonable thing for us to do in the field of aquaculture, we quickly determined that the striped bass, or rockfish as Marylanders call it, would be our target.

We have always believed that the warmed water discharges from our powerplants had more beneficial usages than were being taken advantage of. At the location of this particular facility, the water is just transitioning from freshwater to saltwater, an ideal situation for the rearing of striped bass. We conceived and built a pilot-sized facility to grow the fish to advanced fingerling size, to be released to the Chesapeake Bay. Our objective was to determine if this could be done on a pilot scale and whether or not larger size aquaculture facilities should be incorporated into new powerplant sites.

A secondary objective was to determine what role hatcheries might have in increasing the bay's population of our prized rockfish. Our target is to be able to raise a million fish a year to the 2-inch size for release, keep a few larger ones for brood stock and full life cycle studies, and to provide research and academic institutions with fish of various sizes for their work. This is our third year of operation, and our accomplishments to date have been modest.

In our first year we released about 25,000 fish, in cooperation with the Maryland Department of Natural Resources, to the Nanticoke and Choptank Rivers. These fish were marked and, based on later sampling, it was determined that that release provided 50 percent of the production in the Choptank River. In addition we have donated 120,000 fish to researchers. Last year, we lost nearly all of our fish. Scientists believe that last year's experience in the natural environment was equally devastating. Right now we have about 100,000 fish that are in the 2- to 4-inch size range, and plans are to release them within the next couple of months.

Our contributions to the body of knowledge about intensive aquaculture are a lot more significant than the number of fish that we have released.

We are the only facility using warmed water in intensive culture of striped bass.

Since we began the operation of our aquaculture facility, we have helped to identify a viral infection which seems to be fairly prevalent among the small fish. Last year at this time we thought it was a significant factor in the mortality rate. We now believe, based on further work this year, that it probably is not fatal.

We have studied the effect of pH fluctuations and temperature fluctuations. Interestingly enough, we find the fish are more tolerant of fluctuations in these variables than we originally thought.

A significant portion of our operation is monitoring the water flowing through our facility. This activity provides a database by which we can guage yearly fluctuations in the upper bay system. Interestingly, this year, in spite of low rainfall, we have noticed extremely low pH values. That is opposite to what conventional wisdom would predict. At this point we do not know why it is happening, but we will be following it very carefully.

We have learned a lot about nutrition in an intensive aquaculture facility. This year we have made major advances in understanding potential sources of disease that are associated with the live diet required by the striped bass.

We are now designing next year's program, and we hope to confirm the results of our studies on the effects of pH and food-related contaminants in the fishes' early life state. We will be working on a microcapsule food form and beginning genetic engineering efforts to produce a faster growing fish.

It is particularly distressing that the yield from our Nation's seafood industry is not maintaining pace with the increasing consumption of our citizens. The existence of the hearing today indicates that this subcommittee shares that concern. Most experts believe that our oceanic fisheries are now being harvested at or near maximum sustainable yields. Our coastal and inshore fisheries are clearly being harvested above maximum sustainable yields, and the data on the Chesapeake Bay provide stark evidence of that. Of the three historically important fisheries, the blue crab, worth $32 million in 1984, is the only bay activity that is producing at high levels. In Maryland we are now under a fishing ban for rockfish, to try to protect the species, and our oyster landings in the Chesapeake amounted only to 1.4 million bushels in 1984. That is less than 10 percent of the peak years.

We have submitted a written statement for the record, sponsored by our chairman of the board, which discusses our feelings on the potential value of biotechnology and aquaculture which could move this Nation's seafood industry in the direction that our agricultural industries have already moved. We no longer depend completely on the natural environment to provide the Nation's source of meat. In a similar way, there are clearly things that we can do to augment nature's bounty of seafood. We will not get there easily, and we will not get there without a significant financial commitment.

Our modest aquaculture efforts need to be expanded. We believe that with adequate research and development striped bass can emulate the salmon and the east coast oyster can outdistance the Pacific coast products. But the leadtimes required are long. Hatcheries take 5 to 7 years to reach their potential. Biotechnology can advance aquaculture, and these advances in turn can help the seafood industry. In addition, we need a clean natural environment in which the product can be grown. Business and industry have a vital role to play in this effort. Without stretching my imagination, I believe that there are many powerplant sites up and down this Nation's coastline which are valuable potential aquaculture sites. A sustained, long-term commitment by academia, industry, Government, and our citizens will be required to clean up our Chesapeake Bay. Expanding our sights to the Nation's waters as a whole, and reestablishing our U.S. seafood industry to provide for an increasing demand requires an even larger commitment. A lot of money has been devoted to basic and applied agricultural research, and it has created an efficient food production system which feeds this country and portions of the world. Aquaculture needs support in a similar fashion. The Federal Government has to get deeply involved to make this happen.

In conclusion, I would like to announce that the Baltimore Gas & Electric Co. will be releasing about 200 rockfish, averaging 18 inches in length, to the Chesapeake Bay next month. The release will take place at the mouth of the Severn River, and the details of the event are being worked out. The impact on the bay itself will obviously be miniscule, but we hope by this release and future ones to continue to raise the level of awareness of the general population to this problem. It is our hope that members of the subcommittee and the staff might be able to join us in this event.

Madam Chairwoman, this concludes our oral presentation. We thank you for the opportunity to be here this morning, and we would be happy to respond to any questions.

Ms. MIKULSKI. Thank you.

[The statement of Bernard C. Trueschler follows:]

PREPARED STATEMENT OF BERNARD C. TRUESCHLER, CHAIRMAN OF THE BOARD, BALTIMORE GAS & ELECTRIC CO.

INDUSTRIAL POTENTIAL OF BIOTECHNOLOGY IN AQUACULTURE: EMPHASIS ON THE SEAFOOD INDUSTRY IN CHESAPEAKE BAY

For the Subcommittee on Oceanography, Barbara Mikulski, chairman.

Madam Chairman and Members of the Subcommittee: My name is Bernard C. Trueschler. I am the Chairman of the Board and Chief Executive Officer of the Baltimore Gas and Electic Company. Baltimore Gas and Electric Company is an investor-owned utility engaged primarily in the business of producing and selling electricity and purchasing and selling natural gas. The Company, which is the oldest gas utility and one of the oldest electric utilities in the United States, serves an area which includes Baltimore City and all or part of nine Central Maryland counties. The area served with electricity approximates 2,300 square miles with 2,343,000 residents while the area served with gas includes 600 square miles with a population of 1,807,000.

I appreciate the opportunity to present our thoughts on the potential of biotechnology in marine and estuarine aquaculture. In preparing these comments we spoke with a number of individuals from different parts of the country whose backgrounds ranged from academia and Sea Grant extension to those who have commercial interests in seafood or aquaculture. This presentation is not intended to be an all inclusive look at biotechnology and aquaculture nor does it profess to represent the views of the individuals we have relied on for technical input, although many of their ideas are incorporated to some degree. Nearly everyone thought there was enormous potential in the coupling of biotechnology with aquaculture, but nearly everyone was equally cautious about raising the expectations for immediate payoffs.

First, I'd like to say a few words about why a utility executive is testifying on aquaculture and biotechnology and then specifically let you know about our program in aquaculture and Baltimore Gas and Electric's commitment to a clean Chesapeake Bay. The Electric Power industry has had a long association with aquaculture because of our thermal effluents. There have been numerous attempts to capitalize on warmed water discharges by using them to increase growth rates of various aquatic organisms. Much of the early work was summarized by the Electric Power Research Institute (EPRI), a scientifically recognized research arm of the utility industry. I wish I could cite numerous successes, but there have been few. The reasons span the spectra of business failures, but the two most common causes appear to be: 1. The aquaculture technology was not sufficiently developed to take advantage of the warmed conditions, or 2. The two technologies were not compatible because of various aspects or power plant operations. I believe that the entire aquaculture industry suffers from item #1, above, and its use of biotechnology techniques will depend on how well it can circumvent or solve this problem. I will return to this later in may remarks.

The electric utility industry continues to support aquaculture in a variety of forms. Baltomore Gas and Electric Company decided in 1982 to build a pilot scale aquaculture facility to rear the state fish of Maryland, the striped bass, or as it is better known in the Chesapeake, the rockfish. As with most corporate investments, the decision to build this facility resulted from a variety of converging interests. One of our corporate goals is to seek products from materials we or others are now discarding. The aquaculture facility was designed to investigate the use of our thermal effluent. I emphasize it is a pilot scale facility. It is designed to determine the potential for this technology to be expanded and incorporated into the design of new power plants.

Three other BG&E projects emphasizing recycling of materials are: first, the use of fly ash, the airborne particulate residues from coal combustion, as structural land fill; second, construction of a facility at the Back River Sewage treatment plant to collect, process and pump methane gas from the plants anaerobic digestion process into our natural gas pipelines. This gas was formerly flared off at the sewage plant and wasted. Third, the use of garbage, processed by Maryland Environmental Services into refuse derived fuel, at our C.P. Crane Power Plant. This synergism eliminates Baltimore County's need for extensive use of land for garbage disposal and provides us with an alternate source of low sulfur fuel to generate electricity. I mention these three additional technologies because they were already well developed, at least at the pilot plant level, before we expanded them to commercial scale. This effect of moving from experimental (research), to intermediate (development), to commercial scale is as important in aquaculture as it is in engineering or agriculture.

A second corporate goal is to be responsive to the quality of life in our service territory. The enhancement of life for our employees and customers is important to us. It is this intangible that keeps our area and economy vibrant and growing. Two of the environmental programs at BG&E exmplify our efforts in this area.

We have accumulated a large environmental data base on the Chesapeake Bay near our Calvert Cliffs nuclear generating plant. These data, collected from 1967 to 1982, has cost BG&E over $13,000,000. We have recently contracted with the Estuarine Research Federation, an international confederation of estuarine research scientists, to provide peer review for a book that will scientifically examine this data base. The careful review of such data bases, subject to proper scientific review, will demonstrate that we care about the environment and will support high quality science to find answers to environmental questions. It is our belief that properly designed studies can indicate if, where, and when improvements must be made in our operations.

More germane to the topic of this hearing is our aquaculture program. We are currently adding rockfish to Chesapeake Bay in a cooperative program with the Maryland Department of Natural Resources. We hope this effort will aid in the restoration of rockfish stocks to their formal levels but, in addition, the stocking of this species is a symbol of our commitment to the quality of life for our citizens and our commitment to the cleanup of the Chesapeake Bay. I am particularly proud that we were the first utility in the area to voluntarily make this commitment, but I am even prouder that two more of the Bay areas utilities have, during this past year, initiated programs to help in the restoration of the rockfish. In addition to the striped bass restoration, we are actively trying to prevent shoreline erosion on our properties, and we are donating our Environmental Programs Directors time to the state for one year so he can initiate a new Chesapeake Bay clean up program.

Lastly, I must emphasize that although these are things we currently support, our primary business and obligation is, and will be, to offer our customers a reliable source of energy at as low a cost as is compatible with maintaining a clean environment and a proper return to our shareholders.

SEAFOOD, AQUACULTURE, AND AGRICULTURE

I now would like to turn your attention to some rather disturbing figures about the seafood industry. In 1984 the United States imported nearly $3.7 billion worth of fish and seafood products and exported only $0.8 billion. That is a $2.9 billion deficit in our balance of trade. This deficit is increasing in the high value items such as shrimp and salmon. For example, since 1980 foreign suppliers have increased their market share of shrimp from 55% to 71% of U.S. consumption. Only a small portion of the world's supply of seafood (about 10%) was produced by aquaculture; however, the production capabilities of world aquaculture are growing in the same areas as our seafood imports—shrimp and salmon. These figures indicate the high demand for fish and seafood products in this country.

It is clear that we are not producing enough seafood to meet the demand. These data demonstrate a fallacy concerning market place competition between aquaculture and traditional fisheries. These two forms of producing food for our country are not competing with each other as much as they are with agriculture. Neither method is producing enough food to effectively compete with agriculture. If fish and shellfish are to become greater parts of our diet they must offer better value than protein sources such as chicken, pork and beef. These formidable competitors, with enormous market strength and large research and development efforts to back them up at all governmental and industrial levels. For example: today there are agricultural research experiment stations in every state and territory in the United States. In the states of Maryland and Virginia there are two agriculture experiment stations, approximately 20 field research farms, plus a number of cooperating farms. These figures do not include the laboratory scale work going on in various universities throughout our region.

I would not be suprised if each member of this subcommittee has some agriculture research facility, designed specifically to take the laboratory scale experiments through a pilot field testing, in their district. These branch research and development facilities specialize in tailoring agriculture for their specific geography and climatic conditions. How many could say the same for marine or estuarine aquaculture? I suspect that only the Representative from South Carolina could hold his head high in this regard because his state has just built one of the first facilities that has the potential to address the pilot level problems in aquaculture. With this center, the state can examine the viability of candidate species for controlled culture, as well as develop, test, refine and demonstrate production technologies on the pilot plant level. Until we have regional centers capable of addressing this intermediate scale in aquaculture development, there will continue to be an unacceptably high rate of business failures relative to the potential returns in aquaculture. Again you must remember the competition is agriculture and even through they have enormous financial resources relative to aquaculture they have the pilot scale research funded by major farm machinery, pharmaceutical, and chemical companies and government at all levels supports additional research.

Aquaculture is simply too small a market for these companies to be interested in developing or registering products for its use. It is not only the commercial sector that has, for obvious economic reasons, failed to develop the potential for aquaculture, but the government is equally indifferent. Regulatory authority for aquaculture, because it deals with water, is most often placed under fisheries managers whose responsibility is maintaining natural stocks. Many of these individuals do not understand the differences between regulation of wild harvest and regulation of farmed products. This makes as much sense as using wildlife managers responsible for cattle ranching or chicken farming. Interstate commerce of agriculture products could not have developed if current regulations, pertaining to aquaculture and designed to protect natural populations, were applied to its products. The National Aquaculture Development Plan, after an arduous five years, was finally passed by Congress in 1983, but has never been implemented. Many of the recommendations of that plan are as valid today as when the initial outline was developed in 1977.

Overall, total expenditures by state agricultural experiment stations and related agricultural research is in excess of $600 million per year (both federal and state funding). These funds support the basic and applied research base from which U.S. agriculture has become an efficient food producing system that exports rather than imports products. This is a substantial sum of money, but it is only about 20% of the current trade deficit due to seafood products. Recent research indicates that the return on investment for every dollar invested in agriculture research is on the order of 30%-50% per year, and the anticipated returns on investment in aquaculture research and development are at least as high.

BIOTECHNOLOGY AND AQUACULTURE

How does the lack of pilot scale facilities affect biotechnology and aquaculture? The advances being made in biotechnology are primarily the result of years of funding basic research. Basic research has advanced the culture of marine vertebrates and invertebrates to a point where development of pilot facilities is the next step. As long ago as 1978, the National Research Council of the National Academy of Science advocated that the aquaculture activities of the Sea Grant program focus on long term research and development, rather than short term (three years or less) problem solving research. This long term research, including elucidation of the mechanisms by which biotechnology can be applied to aquaculture, lags because of inadequate facilities. Many of the biotechnology advances are the result of our understanding of the mechanisms involved in the transfer of genetic information and how this can be manipulated on a cellular or subcellular level. Without the basic research the level of scientific knowledge would not have advanced to the point where biotechnology is one of the growth industries of the future.

Aquacultural applications of biotechnology are numerous. It is already known that injection of fish with growth hormones will increase growth rate. The next step is to genetically implant the ability to make this growth hormone into the developing fish egg so hormonal synthesis will be carried out by the growing fish. Recent research at Johns Hopkins University has shown that genetic engineering techniques, such as injecting of cloned genetic material into the nuclei or pronuclei of one-celled embryos, can be applied to fish, but our knowledge about, and our ability to utilize the potential application of these and similar techniques, is still in the research phase. There is enough evidence to suggest that similar genetic manipulations may allow much more rapid advances in procedures to tailor fish or shellfish for specific sectors of their habitat, to increase growth rate or to increase disease resistance, than using classical genetic selection. Other potential genetic manipulations include production of sterile organisms, all males or all females, thus decreasing the variability in growth rate and yielding a more uniform product for the processor. These same techniques may help the fisheries manager in restoration, by providing a female dominated population to increase reproductive potential or in stock assessment by establishing specific recognizable genetic marks.

The major difficulties restraining genetic experimentation on commercial or sports fish are the lack of continuity in funding and the lack of facilities scaled to maintain sufficient broad stock over the time intervals needed for genetic work. It typically takes 2-5 years to rear one generation of a commercially important species. Unless 3-5 generations can be maintained there is little hope for major advances with commercial species. These same difficulties face experiments designed to investigate the effect of genetic manipulations on feeding efficiency, assimilation efficiency, disease resistance or other areas of biological and economic importance.

The most promising of the genetic technologies for the immediate future is the use of polyploidy, increasing the number of genes, in fish or shellfish. For example studies at the University of Maine have shown that triploid scallops have muscles, the edible portion, 80% larger than the normal diploid individuals. Triploid oysters were found to grow 40% larger, in the same period, than their diploid counterparts. The exact mechanism for the growth enhancement has not yet been determined, but it is hypothesized to be due to either increased heterozigosity, or the suppression of reproduction in the triploid individuals. Researchers in Maine are conducting triploid studies on two species of clams, one, the soft clam, *Mya arenaria*, is an important product in Maryland. Investigators on the West coast have shown that triploid Japanese oysters, *Crassostrea gigas*, do not develop gonadal material until after they have grown to market size. This technique, if perfected, will extend the marketing period for a greater portion of the year.

The potential for biotechnology to provide new and specific cures for a variety of diseases is enormous. Disease has been a major problem for the aquaculture industry. Strict FDA rules and the lack of economic incentive for pharmaceutical companies to register drugs for aquatic species have been major impediments to effective disease control in aquaculture. Many of the diseases of fish and shellfish are bacterial or viral in origin. Work on the means to rapidly diagnose diseases such as infectious pancreatic necrosis (IPN) by monoclonal antibody dilution techniques is currently underway. The use of recombinant DNA to produce new drugs could increase survival during critical early life stages. Recombinant DNA techniques are being used in North Carolina to develop a means of controlling bacteria in blue crab shedding systems.

The culture of algae, either unicellular or macroscopic, offers many opportunities for pharmaceutical development. New techniques for filtration of large quantities of unicellular algae are being studied in a National Science Foundation Small Business Innovation Research (SBIR) grant. Union of the unicellular algal culture methodologies with someone knowledgeable in the types of products required by the biomedical industry is needed. The SBIR grants are a means of leveraging federal contributions with those from private industry. Another SBIR grant has been awarded to utilize biotechnological techniques to increase the quantity of agarose, a product required by the biomedical industry, in the macroalgae *Gelidium*. Agarose is currently extracted from algae harvested from wild stocks. Several companies are actively engaged in research and development of methods to utilize algae as a source of beta carotene, a vitamin A precursor. Macroalgae such as Irish moss, *Chondrus crispus* and the red seaweed *Gracilaria* are being investigated for ways to increase yields of carrageenen and other phycocolloids, pharmaceutical extracts, animal feedstocks and biomass for methane production.

Molluscan hatcheries have developed to a point where their successes can be enumerated. Virtually all of the oysters being produced on the Pacific coast of the United States come from hatcheries. The State of Washington had an estimated production of 5,000,000 lbs of shucked meats last year. Total Pacific coast production of oysters from aquaculture was about 7,200,000 lbs of meats. The major development responsible for this dramatic increase has been the so called "eyed larvae" technique. Essentially this technique allows a few hatcheries to produce larvae in tremendous quantities at a reasonable cost. The larvae are "harvested" when their pigmented "eye spot" appears and shipped to the customer. The customer has time to set up a large tank with materials on which the larvae set (undergo metamorphosis to a bottom dwelling individual). The larvae are packaged in a cool moist environment for delivery to the customer's site. These larvae are placed in the setting tank. After a few days, the material containing the set oysters is taken to the shore for a "hardening off" process and then planted on the bottom. This frees the grower from the hatchery operation and frees the hatchery personnel from the responsibility of field work. This is similar to the seed company and the farmer in agriculture.

Further advances have been made in understanding the setting stimulus and spawning stimulus in mollusks. In 1982, researchers at the University of Maryland were able to isolate a bacteria that stimulated the setting of oysters. This basic research has continued and we now know that a group of chemicals, mostly neurotransmitters, will stimulate various portions of the settlement process in oysters. Pretreatment of eyed larvae with L-dihydroxyphenylalanine (L-DOPA) results in more rapid attachment of oyster larvae once they are placed in the tanks with the shells. Epinephrine and norepinephrine will cause oysters to set without a substrate being present. This is a major scientific advance because we now have a means to begin to discern the mechanisms of setting in mollusks. Maryland researchers are conducting pilot scale experiments with oyster growers on the west coast. The reason for this technology transfer to the west coast is because we do not have pilot facilities in the Chesapeake region capable of producing eyed larvae with sufficient regularity or in sufficient quantity to do the scale-up.

Another neurotransmitter, serotonin, has been shown to stimulate spawning in a number of bivalves. Rather than rely on crude techniques such a thermal stimuli and a day at the spawning table to determine if oysters and clams will spawn, injection of serotonin has decreased the time to hours. This technique requires refinement and work with other neurotransmitters may provide a more reliable inducer.

Recent work with fish has suggested that lutenizing hormone releasing hormone (LHRH) can be utilized to initiate the reproductive cycle at any time of the year, and the organism will spawn within a few weeks of exposure to the chemical. If this preliminary work proves to be effective with commercial species, many experiments that require waiting for the once a year reproductive period can be speeded up.

Another area for biotechnology development is in our understanding of fish and invertebrate nutrition. Our knowledge of nutrition in most fish and almost all invertebrates is rudimentary at best. The difficulty, both scientifically and practically, lies in the size of the food particle and the necessity of delivering the food in the water. As particle size decreases, the rate at which important dietary components, such as vitamins, are leached into the water increases dramatically. The problem becomes most acute when either food or drugs are to be ingested by larval organisms. Because of this difficulty, larval foods are mostly living organisms such as unicellular algae and brine shrimp or other zooplantkton. Unfortunately, these sources of food are extremely variable in nutritional quantity and quality, and few advances can be made in nutritional studies until artificial diets can be formulated.

Microencapsulation techniques appear to offer the best means for circumventing the size/leaching problems. Typically, these techniques suspend a nutrient or drug in a fluid and then a coating is applied. These coatings can range from a protein to a porous plastic, but manufacturing techniques are expensive. Some companies are working on diets for shrimp and fish and research is underway to determine the proper size diets for molluscan larvae.

Crustacean culture has advanced to the point where shrimp farms in third world countries are predicted to be a major force in supplying the market within the next decade. A number of U.S. companies are exploring this potential throughout the Carribean. Lobsters have been sucessfully cultured and studies on their nutrition are well advanced. This work on the lobster, oddly enough, has been conducted mostly in California; although, important studies have been conducted in Massachusetts. The major deterrent to commercial lobster culture appears to be the cost associated with isolating each individual to prevent cannibalism. In the Chesapeake Bay, major advances in closed system shedding of blue crabs has provided much higher yields of soft crabs for the market. Workers have been able to control the molting process in some other species such as the rock crab, *Cancer irroratus,* by manipulating water temperature and photoperiod. Newer shedding systems are now being used to produce soft rock crabs during January and February. Soft crabs from the Chesapeake have been exhibited by Sea Grant extension personnel in seafood expositions in both Europe and Japan and received a great deal of attention. Workers on the Gulf Coast are investigating the possibility of using the hormones 20-hydroxy-ecdysone, makisterone-A and inokosterone to initiate proecdysis in intermolt stage blue crabs. If these preliminary studies are successful more soft crabs should be made available to the market and over a longer portion of the year.

I believe you can see from these few examples the tremendous strides that are being made, and more can be expected. Domestic consumption of seafood has increased from 10.3 pounds per person in 1960 to 13.6 pounds in 1984. With the latest medical evidence suggesting that it is healthy to eat fish and seafood, the industry is predicting per capita consumption will continue to increase.

CHESAPEAKE BAY SEAFOOD

Chesapeake Bay has been and still is a major producer of fish and shellfish, so increased consumption sounds like good news for the seafood harvester, grower or processor. Unfortunately, this brings us to the most worrysome portion of this presentation. Recent studies by researchers throughout the Bay region, under the Environmental Protection Agency's Chesapeake Bay Program, documented substantial decline in water quality throughout the region. Some studies are continuing and further declines have been noted. Fortunately, the Chesapeake Bay has received national attention and efforts are underway in Maryland, Virginia and Pennsylvania to reverse this decline. It is essential to maintain this effort and to have a clean bay if traditional fisheries are to survive as a viable industry, and if biotechnology advance and aquaculture are to have any impact.

The Chesapeake supports a variety of fisheries, but three: the blue crab, *Callinectes sapidus;* the striped bass, *Morone saxatilis;* and the oyster, *Crassostrea virginica* are of major economic importance and reflect the general trends in the bay.

Blue crabs are sold in two major forms, the typical hard crab and the soft crab. Landings fluctuate greatly from year to year, but since the 1940's Maryland and

Virginia have produced between 40,000,000 and 100,00,000 lbs, and since 1960, with the exception of 1976, have never been below 54,000,000 lbs. Total value of the blue crab fishery was $32,000,000 in 1984 and nearly 17% of the dollar total was from crab shedding. This is the only major fishery of the three listed above that continues to produce near or above historical levels. Thee are estimated to be over 2,000 crab shedding facilities in the United States and nearly 70% of these are in the Chesapeake Bay region. Analysis of the advances being made, by the new shedding facility technology described above, on soft crab production are currently being made by Sea Grant personnel. It is believed there is a significant dollar contribution because hard crabs sell for $0.28/lb while soft crabs average $1.75/lb.

Landing statistics of striped bass and oysters mirror the decline in water quality. Maryland striped bass landings reached their historical peaks in the decade of the 1960's with 1961 landings of 5,400,000 lbs. From 1970 to 1975 landings hovered around 3,000,000 lbs annually and from 1976 to 1984 only one year has exceeded 2,000,000 lbs. The last three years' annual catches have not exceeded 800,000 lbs and we know that there will be no 1985 landings because of the ban on commercial and sport fishing. Since the Chesapeake Bay is a major spawning area for rockfish, this decline in landings has been mirrored throughout the Maine to North Carolina region. In 1974, 14,700,000 lbs of striped bass were landed and by 1980 this was reduced to 5,000,000 lbs. A recent study indicates that this decline in commercials and a similar but less quantifiable decline in sport, fishery landings has cost the 10 state region 7,500 lost jobs and $220,000,000 in lost economic activity. If the 1980 data are projected to the zero landings of 1985 the costs to Maryland's commercial and sport fisheries will be $4,850,000 and $35,188,000 respectively. Obviously some of the sports fishermen will substitute by fishing for other species, but the losses will be substantial.

Oyster landings in Chesapeake Bay are believed to have peaked between 1875 and 1885 and may have reached 17,000,000 to 20,000,000 bushels. Landings averaged between 3,300,000 and 7,000,000 bushels from the 1930's to 1960. In 1960 the oyster disease MSX eliminated a great many of the productive oyster growing areas in the high salinity portions of the bay. Comparison of the Virginia landings from 1951 to 1960 with the post MSX period, 1961 to 1975, indicates a 62% drop in production from leased oyster grounds and 35% drop in public oyster ground landings. Prior to MSX the private leases were 7.6 times more productive (on an areal basis) than the public fishery. The reason for the greater drop in the private fishery is that many growers simply stopped planting seed oysters. By 1984 total oyster landings in Maryland and Virgina were approximately 800,000 and 626,000 bushels, respectively. Thus total landings have dropped to 1,426,000 bushels and the outlook for the future is not bright.

What is even more disturbing is that our oyster packers are being reduced to middlemen. Most of Maryland's oysters are packed in Virginia and even there packers have relied on Gulf coast oyster harvests to provide sufficient product. Although accurate statistics are not available, in 1984 between 100,000 and 150,000 gallons of packed oysters were imported from West coast growers. These were then repacked and sold in local markets as West coast oysters. As indicated before, virtually the entire west coast production is based on aquacultured products. This is an extremely serious situation. The next step is for the West coast packers to contact the food distributers and cut out the middleman. We desperately need more product to process and sell. This isn't biotechnology, this is business and it is happening elsewhere in the seafood industry.

The Norwegians have developed pen rearing of Atlantic salmon to the point where they are able to air freight salmon to the West coast of the United States. As you travel around the country please note the number of restaurants that now offer salmon. Some of this supply is from U.S. firms and the remainder is imported from Europe. Last year the U.S. imported about 25% or 8,000,000 lbs of Norway's production and another 1,000,000 lbs arrived from other countries. Some of these foreign companies are beginning to build facilities in Washington and Maine. U.S. companies have not been idle. Domsea, a subsidiary of Campbell Soup, produces about 2,000,000 lbs of "pan sized" pen reared coho salmon per year and Weyerhauser has been doing research and development on ocean ranching of salmon for over a decade. In spite of the imports, the aquacultured product does not appear to be hurting traditional fisheries. Most of the cultured salmon are being supplied to restaurants and have expanded the market by allowing fresh products to be available throughout the year.

With adequate research and development, the striped bass has the potential to emulate the success of the salmon and the East coast oyster, *Crassostrea virginica* can out compete Pacific Coast products, but the lead times required for this work are long. Hatcheries typically take 5 to 7 years to begin to reach their potential. Large sums of money invested in short term projects do no good. It takes 2-5 years to raise a 2-5 year old organism and neither biotechnology nor money can alter this rate. Biotechnology has potential to make advances in aquaculture occur at a faster pace than agriculture, simply because there is much farther to go. These advances can help the seafood industry; however, unless we have a natural environment in which the product can be grown, and a regulatory climate in which business can flourish, the heritage of the Chesapeake Bay as a major seafood producer is in jeopardy. Sustained efforts by academia, industry, government and the citizens will be required to clean up the Bay and reestablish its seafood industry. Biotechnology and aquaculture can improve future harvests, but without a long term commitment, five to ten years from now another group will be listening to a new set of data with the same conclusions.

Madam Chairman, this concludes my prepared remarks. We would be delighted to answer any questions the subcommittee may have, and we would like to conclude by commending the subcommittee on holding a hearing on this important issue to the State of Maryland and the Nation.

Ms. MIKULSKI. We would like to welcome Dr. Arthur Karuna-Karan to present his testimony that pertains to feeding the hungry in the world.

STATEMENT OF ARTHUR KARUNA-KARAN

Dr. KARUNA-KARAN. Madam Chairwoman, members of the committee, I request that the written testimony be entered in the record and I would like to present an extemporaneous account.

Ms. MIKULSKI. Yes.

Dr. KARUNA-KARAN. Cyanotech Corp. is a microalgae company, and there are only a handful in the world; and we are fairly confident that we are the leaders.

What is microalgae and what is so great about it?

Microalgae are nothing more than microscopic plants, and there are tens and thousands of these species available, and they produce tens of thousands of high value products.

The great advantage of microalgaes is that in 8 hours or less they double. Just imagine if you had an agriculture based on a harvest every 8 hours. So that is the kind of revolution we are talking about.

What is so great about Cyanotech? People have been working on microbiology for a long, long time. The uniqueness of our approach is concentrated on two things: One, our technology is based not on pure microbiology, but on applied chemical engineering. Dr. Cysewski, who comes from the State of Washington, is a chemical engineer by training, he was the first to apply engineering principles to large scale culture of microalgae.

He has taken a biological science dealing with cultures in small flasks to acres of ponds producing microalgae by 20, 50 tons a year. So that is a revolution that he has introduced.

Unfortunately, he was not able to be here.

The second major difference is this: We have looked at microalgae from a short-term business point of view; that is, we have said we want to get profits out of microalgae for a simple reason. We are entirely supported by investors, and private investors do not like to wait very long for return on their money, so we have concentrated on high value products and also products which have established markets.

The idea is we want to get Cyanotech into a profitable position very quickly, so the luxury of gene splicing and looking at cancer cures are not for us for the time being.

As of now we have four products available. The first product is a protein supplement that is being sold in health food markets called Spirulina. It has the highest concentration of protein in any vegetable source. It used to come from Mexico where they harvested it in natural-occurring growth in the lake.

The FDA will not allow the Mexican product now for human consumption due to contamination problems.

The second product is beta carotene and that has again an established market. The only source that is available today is a synthetic source that comes from Hoffman-Laroche, Switzerland. We have an algae containing 10 percent beta carotene; the next best source is carrots, 0.01 percent, so we have a definite advantage.

The natural vitamin commands a premium over the synthetic product.

We have also found we can produce certain extremely high value fluorescent pigments, and they are presently being used in diagnostic research. I have two of them right here, and they sell for $15,000 a gram.

The fourth product is our biggest product, which will have a significant impact on agriculture in this country and abroad. We have developed a nitrogen fixing microalgae into a dry form. What this means is you have a powder rather like yeast powder, and you can apply it on soil, moisten the soil and then you will have a growth of this algae on the surface of the soil.

The algae takes atmospheric nitrogen and converts it to nitrogen fertilizer available to the plants. What you have is a natural form of chemical fertilizer. It will be a slow release; that is, it will be constantly releasing this fertilizer in minute amounts into the soil.

We have carried out extensive experiments to show the effacacy of this fertilizer and here are some photographs to show this.

The market for nitrogen fertilizer in this country is about $6 billion a year, and all of it requires fossil fuel—mostly imported oil—which is responsible for producing the bulk of the chemical fertilizer. Here we are talking about replacing maybe not all of it but a significant amount with a natural self-reproducing organism.

In certain areas such as the citrus industry chemical fertilizers have turned out to be, in fact, harmful; and if you can only use a natural nitrogen fertilizer, not only will it be beneficial environmentally, but the industry itself will be at an advantage.

On top of all of that, we are cost competitive. The Congressmen from Washington may know Mr. Max Gurvich who will be introducing this product for the home and lawn market next month. Hopefully by the end of the year we will get into the ornamental plant market in California, and then we wish to go into the citrus industry in Texas and Florida.

We have our own production facility on the Kona coast of Hawaii.

About a year ago we talked to venture capitalists and we told some from Princeton, New Jersey that we were planning on setting up our production facility in Hawaii, and he immediately dismissed us as a frivolous company, wanting an excuse to go to Hawaii.

Kona coast happens to have the highest amount of sunlight of any place in the United States and extremely low rainfall. The State of Hawaii at the National Energy Laboratory of Hawaii, there is access to deep ocean water which means extremely pure water with high levels of nutrients.

One of the things we have done in our company is to take microalgae normally grown in freshwater and adapt them to grow in saltwater and that reduces expenses quite significantly.

Use of freshwater has its problems. There are some algae companies in southern California that use freshwater; but when you are using irrigation water you have the problem of heavy metals; and if you get heavy metals into a product for consumption you will have problems. That is our facility in Hawaii, 2.1 acres of algae farms for the time being, and we will be expanding very rapidly. We have had excellent support from the State of Hawaii. Last Monday we had an official opening of the plant.

Ms. **Mikulski**. Doctor, is there a final point you would like to make?

Dr. **Karuna-Karan**. I wanted to mention one thing. We have not had any kind of Government support whatsoever, and it would make a significant difference in terms of research since some of the long-term projects clearly do not fall in the area of support from private investors.

Ms. **Mikulski**. You have had support from the Government through the Tax Code? Venture capital happens because of the Tax Code?

Dr. **Karuna-Karan**. Unfortunately, we were unlucky in getting money from venture capitalists per se. We had to depend upon private investors.

[The statement of Arthur Karuna-Karan follows:]

Prepared Statement of Arthur Karuna-Karan, President, Cyanotech Corp.

Microalgae are a potent source of high value products ranging from nutritional supplements such as vitamins and unsaturated fatty acids to specialty chemicals such as biocides, anti-biotics, pigments and anti-cancer drugs. There are literally tens of thousands of species of microalgae and more are being discovered all the time. Given that microalgae double in cell volume in eight hours or less, the development of large scale technology to culture pure single species of algae could eventually lead to an industry rivaling many aspects of agriculture.

Until recently the development of a viable industry based on large scale culture of microalgae was hampered by two features. First the emphasis was on high volume low value products such as basic food materials and substitutes for fossil fuels. Secondly the scientists involved in the development of culture technology have by and large tended to be biologists by training and this has limited their ability to handle the scale of problems as well as design acre size culture ponds.

At Cyanotech Corporation the technology is based on the pioneering work of Dr. Gerald Cysewski, a chemical engineer by training (Ph.D., Berkeley) and an algologist by avocation. His developmental work on large scale culture technology at the University of California, Santa Barbara, was supported by grants from the National Science Foundation and eventually lead to an offer from Battelle Memorial Institute to set up an algal research unit at its facility in Richland, Washington. After several years of highly productive research and development Dr. Cysewski left Battelle and in May 1983 teamed up with Dr. Arthur Karuna-Karan (Ph.D., biochemistry from Purdue and M.B.A. from Harvard) to set up Cyanotech Corporation.

By applying the principles of chemical engineering and bioengineering to large-scale algal culture, Cyanotech has been able to transform a laboratory-based biological science into an economically viable production system. Process patents and proprietary knowledge are expected to give Cyanotech a lead time of several years before any serious competition emerges.

Some of the important advances already achieved by Cyanotech scientists are listed below:

1. The development of simplified and highly efficient methods of extraction and purification of phycobili-proteins. These fluorescent pigments can now be produced in very pure form at a cost which allows us to reduce the market price by 70% or more, allowing their use on a much wider basis. We are producing by a novel proprietary method two forms of phycoerythrin, and also phycocyanin and allophycocyanin. These dyes should see an increasing use in diagnostic medicine, particularly Immunology, the most rapid growth area in medicine (currently about 40% p.a.).

2. Spirulina, the alga widely used as a health food supplement, has been adapted to sea water growth media, allowing its culture on a large scale in pure deep ocean water in Hawaii. Optimum conditions of growth are being developed, and strain selection has been carried out to maximize production and minimize costs.

3. The algal biofertilizer has been developed as an active dry formulation with long shelf life. On application to soil and watering, it immediately commences to grow and multiply, forming a soil cover which fixes nitrogen from the air for plant growth. We have developed a strain that is resistant to copper, which can eliminate competition from other organisms. We are currently developing improved methods of bulk drying, to handle the anticipated large volumes.

The biofertilizer is currently undergoing field trials to establish its value for use on ornamental plants in the home and garden commercial greenhouse and on golf courses and lawns. We are investigating alternative formulations for specific markets, and also a "universal" mixture, to determine the optimum form for market presentation.

4. In the production of beta carotene for vitamin use, we have developed new methods of harvesting the algae—formerly the major stumbling block to commercialization. These algae are also being adapted to growth in sea water, while maintaining their remarkably high carotene content, and methods of extraction and purification of the carotene have been developed. We have processes to produce three forms of carotene: (i) a suspension in vegetable oil, with minimal processing, to meet "all-natural" requirements; (ii) a pure (FDA specification) carotene using standard food oil-industry solvents, and (iii) a purified form prepared solely with the use of good-grade solvents which are on FDA's GRAS (generally regarded as safe) list.

5. Studies on tocopherol production in algae are leading to an increased knowledge of factors controlling levels of this vitamin. We are studying a variety of species and subjecting them to assorted stress conditions to increase the levels of tocopherol.

6. A patent has been filed to protect the technology of our exclusive pulsed wave flow system for algae culture. A patent has also been filed on DNA cloning on microalgae. Both patents will cover U.S. and foreign territories.

Projects for future development include eicosapentaenoic acid (EPA—believed to prevent atherosclerosis and heart disease), plant growth regulators, coloring agents for food and cosmetic use and C^{13}-labelled biochemicals. Strain selection and genetic engineering to produce higher levels of desirable compounds will be coupled with development of simplified methods of purification, to minimize production costs.

Cyanotech Corporation's business strategy centers around the rapid development of easily marketable high value products from unique and proprietary technology applicable to large scale culture of microalgae. Implicit in such a strategy is a business philosophy that calls for the use of investor funds to create revenues leading to profitability, a refershing change from the staggering research expenses burdening most of the so called biotechnology companies. Cyanotech has commenced production of four products: beta carotene, Spirulina, algae nitrogen fertilizer and fluorescent pigments. Two more products, tocopheral and eicosapentaenoic acid (EPA) are expected to be in production next year. At the same time, active research effort is being carried out to identify commercially viable algal sources for biocides, pharmaceuticals and other high-valve specialty products. Conservative projections indicate breakeven by fourth quarter 1985 and net revenues in excess of $20 million a year by the fifth year, based only on the first four products.

Cyanotech's first large-scale culture facility has been constructed at Keahole Point in Kona, Hawaii for the production of Spirulina and beta carotene. Purchase orders have been received for our entire production of Spirulina and beta carotene for the next 12 months.

Cyanotech has held fruitful discussions with several major corporations with respect to financing of research programs to screen algae for additional products. Products in this category include pigments for the cosmetics and food industries, antineoplastic agents, antibiotics, algal toxins for use as bactericides, fragrances, etc. Such funding will be negotiated as grants in return for the right of first refusal to market products resulting from the relevant research programs. One such grant was received last year and another is in the final stages of negotiation.

GOVERNMENT SUPPORT

Cyanotech has been most fortunate in receiving enthusiastic support from the State of Hawaii. Approval has been given for locating the first stage of large scale culture ponds at the Natural Energy Laboratory of Hawaii in Kona, on the big island. A five acre site has been allotted to us with access to power, deep ocean water and fresh water. An additional ten acres have also been made available on a lease basis. Governor Aryoshi has consented to officially open the Cyanotech production facility on July 8, 1985. Finally Cyanotech has applied to the State of Hawaii for a long term loan from the funds set aside for support of aquaculture in the state and indications are that the loan would be approved.

Ms. Mikulski. Dr. Portier, from Louisiana State University, whose research deals with pollution cleanup and some of our really significant problems.

STATEMENT OF RALPH PORTIER

Dr. Portier. Microorganisms have been used by man for a millennia in the treatment of liquid and solid wastes. The modern publicly owned water treatment plant is an example of a conventional microbiological system for the treatment of liquid domestic wastes. Highly toxic organic wastes produced by chemical/petroleum industries along the industrialized east coast, and the industrialized delta of the Mississippi River in Louisiana, are not readily amenable to similar conventional microbiological treatment. The problem is not necessarily inducing a particular microbe to degrade a particular toxicant—although toxicant-specific microbes may be necessary for certain compounds such as PCB's and dioxins—nor is the problem simply seeding industrial wastes with whole microbes—there is a question of how efficient organisms can degrade pollutants which tend to bind to soils and sediments—rather it is a combination of these and other factors.

James B. Johnson and Susan Robinson, coauthors of Genetic Engineering and New Pollution Control Technologies—1984, Noyes Publication, Park Ridge, NJ—noted that the major breakthrough in biotechnology—both aquatic and marine— will occur first at the "end of the pipe" and later "down in the dump." I would like to briefly describe our current efforts in addressing both industrial effluents and abandoned hazardous wastes, research funded by both State and Federal agencies and the private sector. First, "down in the dump," which is where we started—and still are.

Biotreatment of a Superfund site. Approximately 255–275 million tons of hazardous wastes are annually generated in this country, of which only 40 million tons are regulated by EPA [Source: Office of Technology Assessment, Congress of the United States]. These wastes are defined as solid waste—solid, liquid or gas—or a combination of solid waste which, because of its quality, concentration or physical/chemical characteristics may cause or contribute to irreversible illness and pose a substantial present or potential risk to human health. In the State of Louisiana alone over 300 waste sites have been targeted by the EPA for evaluation of potential hazards. Four sites are on the Superfund list.

Our department at Louisiana State University is currently completing laboratory field simulation tests on the biological treatment of one of these Superfund sites, the Old Inger Oil Co. complex located along the industrial corridor between Baton Rouge and New Orleans. Field pilot studies, designated by EPA as phase 3 operations, will begin on the site in August 1985.

This project, to render safe a Superfund hazardous waste site using microbiological approaches, developed earlier in NOAA, Office of Sea Grant supported research in aquatic and marine toxicology, is not only the first such effort in region 6, EPA, but also, nationwide. As shown in the graphics provided—figs. 1, 2, 3, and 4—substantial cost savings for this approach is projected. Immediate savings of $1,989,300.00 is anticipated using a biotreatment approach as compared to the traditional offsite landfill treatment—additional costs and public health risks in a landfill approach are not reflected in these figures. Not only is biotreatment a lower cost strategy but it is also a permanent solution. This is particularly important to Louisiana since this Superfund site is only 35 miles upriver from New Orleans and the adjacent highly productive estuaries.

Immobilized Biotreatment Systems. Next, "the end of the pipe." The Old Inger Oil site is an example of seeking technological solutions after the fact. The most practical, cost-effective and commercially attractive place to deal with toxic chemicals produced by our industries is at the point source—the refinery. We have been developing a point source biotreatment system for use in industries, particularly those located in a coastal zone and, of course, by the maritime industry which services these refineries.

Three biocatalyst systems have been developed for freshwater and brackish water biotreatment of phenolic wastes—the major industrial contaminator found in drinking water along the Mississippi River. Funded by NOAA, Office of Sea Grant, a pilot plant version of one of these systems has been constructed in our laboratory where we have completed tests on lowering the levels of chlorinated phenols from 100 ppm to 1 ppm. The system consists basically of whole microbes, specifically adapted to mixed chlorinated phenols, immobilized on solid matrix support materials. One system consists of immobilized enzymes which achieve a similar result.

We have received support from several major corporations to begin in-plant testing of these systems, beginning in October 1985. I have included a diagram—figure 5—showing a version of this system we plan to construct for the biotreatment of PCB's, with funding from Monsanto Corp.

Private industry is not only interested in investing in the solutions to effluent treatment problems but, also, in the possible monetary gain to be realized in the implementation of this new technology. Included along with the PCB flowchart is information on the performance of support surfaces—figure 6—manufactured by Johns Manville Corp., in our biocatalyst system, for degradation of 1, 1-dichloroethane, a major chemical precursor for the production of vinyl chloride. Officials from LSU and Johns Manville are discussing further research support in this area, including a possible joint venture. We also hope to conduct shipboard tests with our system at a future date.

Concluding remarks. These are just two examples of seed money from Federal programs which have resulted in not only positive gains in "diffusing the toxic waste time bomb ticking in our backyards"—Douglas McCormick, ONE BUGS MEAT Biotechnology, May 1985—but also in promoting private sector funding to bring the technology to market. Investments in this biotechnology field by the private sector occurred only after some 3 years of basic research had been completed. The Office of Technology Assessment, in its report Commercial Biotechnology: An International Analysis, stated that the effort for developing biotechnological solutions will initially require Federal funding with funding shifting to the private sector at a later date.

For these reasons, I support the efforts of the committee to continue basic research funding in marine biotechnology.

Thank you, Madam Chairwoman.

I brought along today some of the marine biopolymers which we have used in our treatment system, which are waste products which we have modified and manufactured into support systems.

I did not bring any microbes; those are still in the lab. We have been taking some of the technology in the private sector; these are support materials manufactured by Manville Corp., and we evaluated because they were available in a commercial quantity, which they would implement this technology.

We have incorporated some of these materials, marine polymer materials and other terrestrial sources, into surfaces which are unique for the attachment of adapted microbes for the detoxification of hazardous waste materials as well as genetically engineered organisms in the area of PCB degradation.

Ms. **Mikulski**. What is that thing you are holding?

Dr. **Portier**. This is a chitin-treated surface for immobolizing new micro-organisms.

Ms. **Mikulski**. Sir?

Dr. **Portier**. It is a high-rise for micro-organisms.

Ms. **Mikulski**. You mean it is a condo?

Dr. **Portier**. Yes, a condo.

We have used holofiber systems which were originally developed for the biomedical and ultrafiltration area, a product manufactured by Amicon, and we have been able to adapt organisms to these surfaces, and you can plug them into a typical manifold and cycle said toxin through these surfaces. Materials modified with Federal and private funding for solving an effluent problem, and that concludes my testimony.

Thank you very much.

[The attachment to Dr. Portier's statement follows:]

Acknowledgements

Research Personnel: LSU

Kuniko Fujisaki, Research Associate
Debra McMillin, Research Associate
Laura Scherbarth, Graduate Research Assistant

Research Grants/Contracts

Development of Biocatalytic Waste Effluent Detoxification Systems for Coastal Zone Industries, NOAA, Sea Grant.

Detoxification of Hazardous Waste Spill Residues Using In Situ Microbial and Enzymatic Techniques. Louisiana Board of Regents Research and Development Program.

FIGURE 1

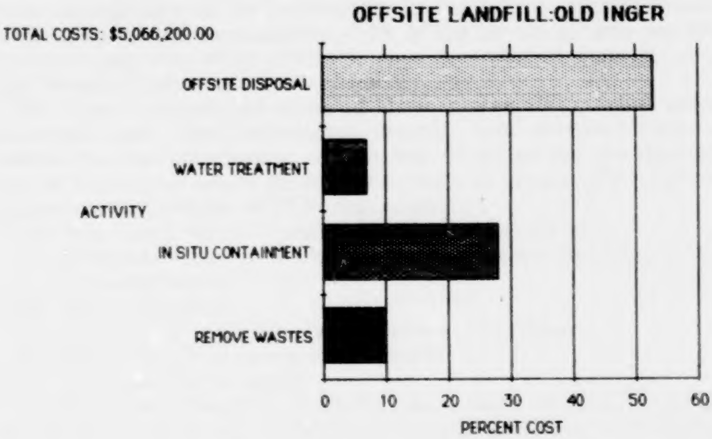

OFFSITE LANDFILL:OLD INGER
TOTAL COSTS: $5,066,200.00
OFFSITE DISPOSAL
WATER TREATMENT
ACTIVITY
IN SITU CONTAINMENT
REMOVE WASTES
0
10
20
30
40
50
60
PERCENT COST

FIGURE 2

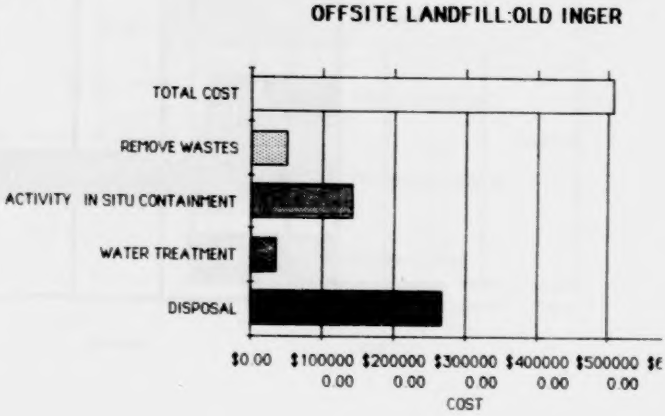
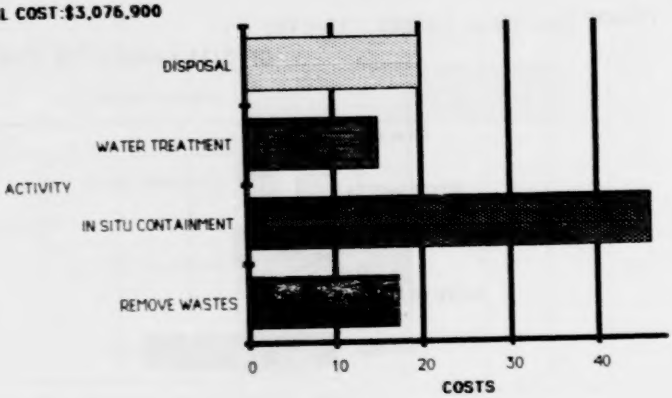

OFFSITE LANDFILL:OLD INGER
TOTAL COST
REMOVE WASTES
ACTIVITY
IN SITU CONTAINMENT
WATER TREATMENT
DISPOSAL
$0.00
$100000 0.00
$200000 0.00
$300000 0.00
$400000 0.00
$500000 0.00
$6
COST

FIGURE 3

ONSITE BIOTREATMENT:OLD INGER

TOTAL COST:$3,076,900



MARINE BIOTECHNOLOGY AND HAZARDOUS WASTE MANAGEMENT/CLEANUP

FIGURE 4

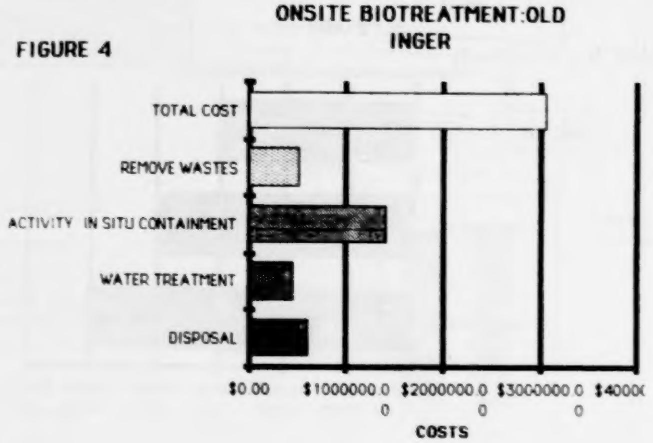
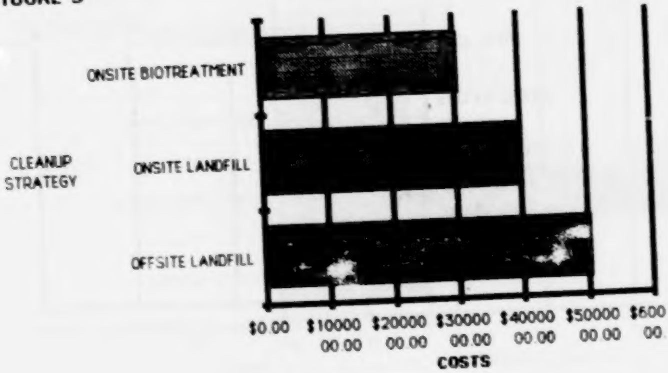
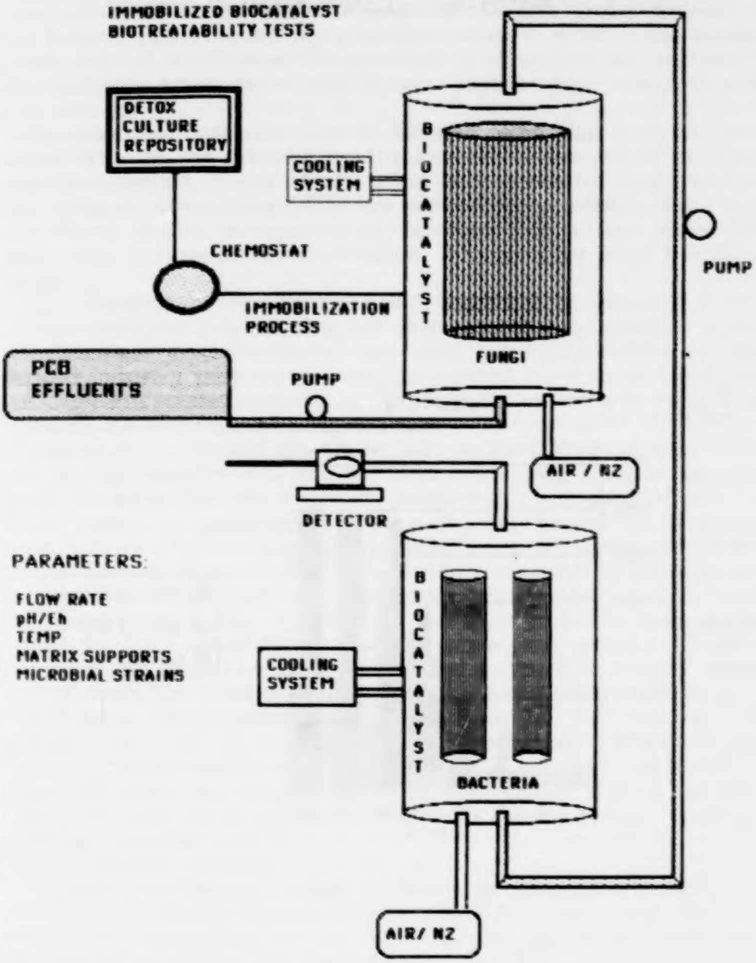


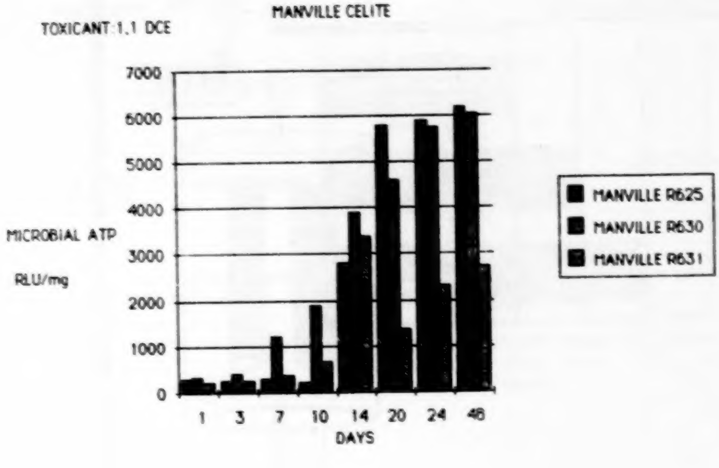
FIGURE 5

SUMMARY




IMMOBILIZED BIOCATALYST
BIOTREATABILITY TESTS
DETOX
CULTURE
REPOSITORY
COOLING
SYSTEM
CHEMOSTAT
IMMOBILIZATION
PROCESS
BIOCATALYST
FUNGI
PUMP
PCB
EFFLUENTS
PUMP
AIR / N2
DETECTOR
PARAMETERS:
FLOW RATE
pH/Eh
TEMP
MATRIX SUPPORTS
MICROBIAL STRAINS
COOLING
SYSTEM
BIOCATALYST
BACTERIA
AIR/ N2

LSU BIOCATALYST SYSTEM TESTS: CELITE PERFORMANCE SUMMARY



Ms. Mikulski. Right on time. I would like to thank you for this most informative testimony. Perhaps we can talk about the role of the Federal Government. My questions relate to what is the appropriate role of the Federal Government to stimulate this industry? My questions would be related to who paid for your research and your activity.

For example, Baltimore Gas & Electric. Who paid for your program? What do the three of you think would be the role of the Federal Government, if any at all, using both direct funding and the Tax Code, in stimulating R&D, tax credits? Do you think there is a role for us to play to continue to stimulate this private sector development, private sector application. Who paid for what BG&E is doing?

Mr. Poindexter. Our company footed the bill. In listening to Dr. Colwell testify and in hearing her responses to your questions, one role the Federal Governmend can play, especially related to the seafood industry that we are very interested in, is to be the focus for long-term strategic planning. As she said, we are way behind in aquaculture as compared to agriculture.

Eventually we would get there; but as Earl Weaver says, "We are playing catch-up ball and we need a few long balls to come in here". By doing that we will avoid possible duplication of effort.

You asked the question: Is there a clearing house? No, there is none, not an effective one. If we could bring the brain power together, here is where we are, here is where we want to be, here are the kinds of things that we could entice private industries to fund themselves, the kinds of opportunities that probably need to be funded by the Federal Government or some other people. All companies do not have the same vision of the future, and yet I think up and down the coast of the country there are opportunities; so if the Federal Government can be the catalyst that makes this happen, then I think that is the role. The actual dollars are not significant compared to what the Federal Government has spent on other programs. An analogy might be the Space Program, to provide that focus for all the knowledge and the long-range strategic planning that goes into it.

Ms. Mikulski. Doctor.

Dr. Karuna-Karan. I must confess that some of the early research was actually funded by the Federal Government. Dr. Cysewski was supported by the National Science Foundation and later on he was with Battelle Institute.

What we have seen in terms of Federal support is the information flow is one sided and the Small Business Investment Research Program—are you all familiar with that?

We have not been able to take advantage of it. Each department sends out a list of topics. If you are lucky enough to find one of your interests in those topics, you can get a grant from them.

Small business innovation research, that is right, we have been looking at that for quite a while but have not been able to find a suitable topic. We have microalgae which can produce antibiotics, and we can come up with a microalgae system to take carbon dioxide from a space shuttle and convert it to oxygen, but we cannot use investors' money for that.

If we could provide the topics to the Government as topics of interest and then they could incorporate them, that would be a big step forward for us.

Ms. MIKULSKI. Mr. Regis McKenna, one of the prime movers in the Silicon Valley miracle, describes a four-point process, from basic research to applied research to product development to the marketing of that product, and those are the four steps he says is from innovation to marketplace utilization. He says this: That the role of the Federal Government is to fund basic research with no immediate practicality. We fund the basic research, applied research is best funded in the private sector using R&D investment tax breaks.

We do the R&D tax credit for applied research, and third, we make sure that our Tax Code considers product development. Taking it from applied research to product development would be flexible enough to encourage venture capital, and that would be the third step.

The fourth step in terms of the marketplace activity then takes us to joint ventures. We then have to take a look at our antitrust laws, which were meant to regulate 19th century monopolies and in no way have any perception of 21st century products. So McKenna says Government funds direct grants in basic research and we move out of the direct funding and use the Tax Code to stimulate R&D in the private sector and venture capital. We make sure that our framework of antitrust laws is such that we do not inhibit, constrict or stifle the kind of joint ventures both within the United States or with other nations. Now, that is the McKenna perception, and do you agree or is this a little too simplistic?

Dr. KARUNA-KARAN. Well, some of the product development area, I think, still requires funding from Government agencies and the like, because from basic research to product development there is a big gap.

The time involved is quite extensive and difficult to get investors to put money in for such a long period. This is where a program like the small business innovation research comes in handy.

Mr. POINDEXTER. That is a good model that has described what has happened in Silicon Valley and could be applied as a framework. One of the missing parts of that model, is there a need for some coordination of all those activities?

Maybe in the case of the microchip and so forth that was kind of self-coordinating. You are talking about a field here that has so many possibilities for the American people in the world, that left to its own devices we may get there, we may not, and we can do things to get there a lot faster than we would otherwise.

Ms. MIKULSKI. Dr. Portier.

Dr. PORTIER. I would like to add one other point. Universities, particularly publicly owned, also receive benefits from the basic reasearch in the form of patent information, exclusivity, licensing agreements; so there is some feedback of public money back into public research labs.

I hasten to add that the areas that I am working in which I want to move into are continuing to be funded by the Federal Government and in those spinoff areas, in terms of direct application to research, we have received some interest from private sector support.

Ms. **Mikulski**. Excuse me. Do you say that you patent a life form?

Dr. **Portier**. Depends on which lawyer you want to ask, how to go about doing such a thing. Many of the things which Dr. Colwell mentioned earlier and which we have alluded to are patentable. There are certain copyright and patentable applications in this type of research. Dr. Chackrabarty in his work a few years back is the landmark Supreme Court case in the patenting of microorganisms, even in the various formulations, pharmaceuticals and the like, packages of information and also things which have some feedback, if you will, into the public university systems for research and development.

They form the additional stimulus within a university community to proceed further. We do not want to be working in an area which is getting us nowhere. Most research scientists are inquisitive and anxious to move into new areas; so it is an incentive as well as a monetary gain to the university in question.

Dr. **Kraeuter**. I was about to make a comment on that model. It is a very good one, but it has limited application; and when we get to producing food, you must remember that this Silicon Valley is based on high value added at the end of the line. You take a chip and can sell it for a lot of money. That is not true with the food. The agriculture research station is an essential step to show the farmer that this is going to work to his advantage. It is a very important difference with a low-value-added product where the returns are not great enough to pay the research and development costs. So you need a little bit of that development stage in here. You are not going to get $15,000 a gram for a fish. I wish we could.

Ms. **Mikulski**. If it keeps up, that is what oysters might be selling for.

I want to come back to some of the bioethic issues.

Mr. **Shumway**. Dr. Kraeuter, your point just now about the micro chip industry, relating that to food, it is a very valid point; but, on the other hand, right now Silicon Valley in California is in trouble because the world market is down. There has been an overabundance. Many reasons enter the picture whereas the market for food is always going to be there. We will always have to eat, a massive population to feed and will be a more constant thing and maybe not as remunerative in the first instance but may be more straight line reliable.

Dr. **Kraeuter**. Look at the recent ups and down in the farm economy and say that is every bit as up and down as Silicon Valley.

Mr. **Shumway**. Not as much. We are still eating that food.

Dr. **Kraeuter**. The individual farmer still sees massive ups and downs.

Any one farm in any one part of the country is narrowly unpredictable. Maybe some of the fruits in California do well this year, but the peach crop is terrible this year and maybe it will stabilize.

Mr. **Shumway**. Mr. Poindexter, you said in developing your aquaculture research station you had no Federal funding.

I am curious why the Sea Grant Program would not have been attractive to you. Did you not apply for it?

Mr. POINDEXTER. No, we did not. We wanted to do this. We wanted to get the facility on quickly, and we thought that by proceeding on our own and avoiding some of the red tape and regulations that might be associated with these grants that we could do that. We try to involve academia and the scientific community through advisory committee structure, but we decided not to go through with the grants. The initial cost of the facility was about $1 million. We will have invested another three-quarter million in operating expenses by the end of the year.

Mr. SHUMWAY. Do you intend to apply for Sea Grant funding or something of the like?

Mr. POINDEXTER. It is a possibility.

We were beginning plans for a new plant, further north of here on the Bush River, and it also looks to be ideal water for this type of a thing, and so we asked ourselves, can we learn enough from a pilot facility that when we built the new plant we could go about it in a big way. If we wanted our sites to go much bigger, we would investigate the opportunities.

Mr. SHUMWAY. Doctor, you mentioned about one of your microalgae that in 8 hours it doubles itself. That is a very interesting point in this context, but in another context it is somewhat scary to uninformed people like me.

In my district in California it was not a marine biotechnology application but in agriculture there was something of this sort proposed, and there was a great fear among people in the area thinking, gee, we are going to have something that spreads and spreads and like a science fiction movie will consume us all. How do you handle that kind of public reaction and, indeed, is that a threat?

Dr. KARUNA-KARAN. Not in the case of microalgae. Algae requires light, so all you have got to do is to bury it and the world would not be overcome by green slime. But we have deliberately kept away from using any genetically engineered organism because of this particular fear. It has been through classical mutation methods. These organisms could occur in nature, not totally manmade. We have the capability to create manmade microalgae, but because of this particular fear we have not done anything about it yet.

Mr. SHUMWAY. I am not sure I understand the difference between mutation methods and genetic manipulation. Is there a difference?

Dr. KARUNA-KARAN. Yes, mutation is happening all the time naturally. Ultraviolet light causes mutations. If the environmental conditions confer an advantage to the mutated specimen, they take over; that is happening all the time.

The species created is basically due to mutation.

Mr. SHUMWAY. You are providing that advantage, not waiting for nature to do it necessarily.

Dr. KARUNA-KARAN. Exactly. Our spirulina is normally a freshwater microalgae, but we found all we have to do is provide the ability for the cells to survive the high concentration of salts; we were able to do that and adapt the algae to grow in saltwater.

Mr. **Shumway**. Do you have the designs to get into the field of genetic manipulation?

Dr. **Karuna-Karan**. We have already filed a patent and we are waiting for approval of the patent, and in the long term we will be using microalgae as host organisms for genetically manufactured products.

Dr. Colwell said earlier on about production coming from genetically manipulated organisms. We feel we have an advantage in certain areas. I do not know how much of this is known now, but people are finding out that a gene taken from a mammalian cell and introduced it into a yeast cell, the product you get is not the same product you get in the mammalian cell. Molecular biologists are finding out they really do not have all the answers. They are finding out again and again new things are happening.

If you are talking about a product from a plant gene, by introducing that gene into a microalgae, the same product can be obtained in a matter of hours as opposed to this normal harvest vine of the plant. That is something that we will be doing in the future.

Mr. **Shumway**. Your effort, you were not successful in getting venture capital?

Dr. **Karuna-Karan**. Right.

Mr. **Shumway**. You have not been the recipient of a Federal grant?

Dr. **Karuna-Karan**. Right.

Mr. **Shumway**. You relied on private funding sources?

Dr. **Karuna-Karan**. Until Continental Insurance Co. came in with a substantial amount of money, the history of investment in biotechnology companies, venture capitalists have shown a herd instinct. When biotechnology was new, everybody went into it. However, biotechnology is not silicon valley, and it is going to take a while to get returns. The herd turned away. We did not get in in 1978 or 1979, in fact, not until 1983, so we had to go to other people besides venture capitalists.

Mr. **Shumway**. The herd would come back if, indeed, they see the promise. It would still be a promise for the future?

Dr. **Karuna-Karan**. Yes, a great deal of promise is there.

Mr. **Shumway**. Why do you not stand up and convince them of that?

Dr. **Karuna-Karan**. It is a question of education. Several of you claim you did not know much about science or scientists; but when a venture capitalist tells you the same thing and he controls the purse strings, it is very dangerous.

Ms. **Mikulski**. That is what we do.

Mr. Miller.

Mr. **Miller**. One question. We have been focusing on marine biotechnology. Doctor, you mentioned what gave your company the breakthrough was that your colleague was involved in chemical engineering, applying those principles. Does that tell us anything about what the Federal role should be in basic research in this area? Should we be looking at chemical engineering more than marine biotechnology?

Dr. **Karuna-Karan**. A fascinating point. For our company we feel the lack of chemical engineers trained in microbiology is a plus because we do not have to worry too much about competition. On the other hand, a combination of that sort would be vital in developing the field. This has already happened in the medical area. Several universities have joined programs where people trained in engineering are getting into the biomedical instrumentation and various types of hybrid fields.

My feeling is it would be easier to teach a chemical engineer biology than engineering to a biologist.

You will find these research results could be brought to fruition as viable venture much sooner by bringing on engineers.

Mr. **Miller.** In one sense the chemical engineering component that your colleague brought to this was almost the applied research phase, right? He was taking this basic research, figuring out how to engineer it beyond the laboratory into these ponds instead of test tubes, right?

Dr. **Karuna-Karan.** Absolutely.

Mr. **Portier.** I would like to mention, being an industrial microbiologist, I disagree with the suppositions that microbiologists cannot function in a chemical engineering mode. Most pragmatic microbiologists are practicing chemists in the same vein. Many times most of my work is chemistry rather than microbiology.

From my own experience there is that crossover that has already occurred.

The brewing industry is a good example of that; so if your point is investment in marine biotechnology is a further investment in cross-fertilization between the engineering in the basic sciences and engineering in the biological sciences area, that is indeed correct and you will see much greater emphasis on this in university communities with this basic research orientation.

Ms. **Mikulski.** I would like to wrap up this panel related to the unintended consequences of research. We are speaking of the dazzling potential in biotechnology just as we compared it to chemistry and physics. Some of our greatest advances presented some of our great problems. Chemistry gives us better life but also Superfund sites.

My question to you then is what could be some of the unintended consequences of your research and also your product development?

For you, Dr. Karuna-Karan, when all those wonderful natural nitrogens are getting into my Chesapeake Bay, are you going to further clog the bay up?

One of the problems with our bay is that with all the nutrients from agriculture, we are now blocking sunlight which is having an effect on the base ecosystem. I wonder what will be the unintended consequences of runoffs of your fertilizer?

For you, Dr. Portier, you have all these little starving organisms sitting around dying to get their whatevers on PCB's. I think that is great. I live down at the waterfront and as they double every 8 hours, I have this question that once they clean up the Superfund site and they are still hungry, what then happens to them? Do they die? Do they start walking up past Pratt Street eating BG&E's PCB's in their transformers? Are we creating the potential for unintended biohazards? But there are the questions of new biohazards whose consequences we have not anticipated and while we are trying to do these tremendous innovations, what are their effects?

Are there unintended consequences there? Dr. Portier, are we creating a godsend or a Godzilla?

Dr. **Karuna-Karan**. I think I did not make myself quite clear. What we are doing with nitrogen is we are removing the possibility of chemicals ending up as pollutants.

I can give you a little instance of what happened 6 months ago. A developer in California was contemplating turning Squaw Valley into a year-round resort and planning to put golf courses there which means tons and tons of chemical fertilizers and they had to get approval from the people around there. The homesteaders did not want chemical fertilizer ending up in their water table, naturally.

So he heard about us, and this was about a year ago. We were barely getting started. He said, "I hear you have a slow released natural fertilizer which will not pollute the water table."

I said, "Well, we will have one probably 1 year from now."

He said, "Tell me all about it so I can get my permit to put up the golf course."

I said, "Sorry, we are not in a position to say that you can put up a golf course with it, if you have not done any studies."

It is what used to be there before chemicals came in.

Ms. **Mikulski**. Say that it is used as comparable fertilizer; it goes into the water. What happens to your microalgae when they hit the water?

Dr. **Karuna-Karan**. The microalgae will be biodegraded very easily. There is a feedback. As the nitrogen is released to the soil, as the concentration goes up, there is an automatic biological inhibition of the reaction. We are trying to meddle with that and prevent that from happening, so it will be constantly releasing nitrogen.

There is a problem today, when you throw tons of chemical fertilizer on the soil and most of it gets leached.

Dr. **Portier**. Your point is well taken with regard to the inherent risk.

The work we are proceeding with in terms of pilot plant evaluation is with an adapted micro-organism.

The Federal Government as well as the international societies, the American Society for Microbiology, for example—there is an awareness of the inherent risk of genetically engineered micro-organisms, and guidelines are being evaluated for handling them. We are looking at an adaption for the foreseeable future and anticipating certain guidelines by the Federal Government in the utilization of truly genetically engineered organisms.

And with PCB work the reason we went—we had mobilization, putting them on surfaces where the organisms remain. That technology can also be localized which would then lend itself to a lot better oversight and licensing by the Federal Government.

Treatment systems which can be evaluated from a biological standpoint as well as a chemical, environmental licensing type protocol is how we envisioned the most immediate applications of micro organisms.

Ms. **Mikulski**. Well, we could keep you all day, but we would like to thank you for your testimony.

Dr. Sullivan.

The committee would like to welcome Dr. James J. Sullivan, the director of the California Sea Grant College Program. One-third of the U.S. biotechnology firms are in California; and what we are interested in hearing from you is the work that you do and where you think the United States is within the international scheme of the development of marine biotechnology. Whether you think we are falling behind, et cetera.

STATEMENT OF JAMES J. SULLIVAN, CALIFORNIA SEA GRANT COLLEGE PROGRAM

Dr. SULLIVAN. Thank you, Madam Chairwoman.

If I appear a little nervous, it is because the last time I sat before a distinguished group like this in Baltimore was when I took my Ph.D. orals.

Ms. MIKULSKI. You are one of our biotechnology products?

Dr. SULLIVAN. No, ma'am. I am out of the political economy department. It is nice to be back in my academic hometown.

I am Dr. James J. Sullivan, director of the California Sea Grant College Program, which is administered by the University of California Institute of Marine Resources. I appreciate this opportunity to appear before the committee today. I will provide you with an international perspective to the discussion of marine biotechnology and give some suggestions for your consideration in response to your invitation.

Before beginning, I would like to express my appreciation to you and to the other members of the committee for your strong support of the National Sea Grant College Program. In turn, I hope that my comments here today will be of assistance to the committee in performing its important and difficult oversight responsibilities.

I will begin by outlining the soaring worldwide growth in aquaculture, then discuss the present position of the United States in marine biotechnology as compared to other nations, and how our position in marine biotechnology presents us as a Nation with enormous opportunities to affect the profitable development of both pharmaceuticals and commercial aquaculture, and to develop the other marine applications described here today. Lastly, I will address some social and governmental factors that are of potential importance to the development of biotechnology.

Aquaculture is a growing worldwide activity. The most recent edition of "World Fish Farming: Cultivation and Economics" now includes data on aquaculture in 31 countries, representing the continents of Europe, Asia, North America, and Oceana, but omitting Africa and South America where only minimal cultured fish production has been reported. Data are given on more than 100 species of cultured fish, 7 species of shrimp and prawn, and 6 species of crayfish.

Global production figures for aquaculture have increased enormously in recent years. World production of fish and shellfish by farming is estimated by the Food and Agriculture Organization [FAO] to have reached 8,107,000 metric tons in 1983, a substantial increase over the 6,490,000 tons produced in 1980 and the 4,955,000 tons produced in 1975. It now represents about 10 percent of total seafood production. Of the world's major regions, Asia and the Pacific are top producers with output that jumped from 3,720,000 tons in 1975 to 6,250,000 tons in 1983. In Japan alone, aquaculture now provides about 1 million metric tons compared to almost zero in 1950. In Europe and Russia, production has risen from 892,000 to 1,278,000 metric tons; in North America from 158,000 to 316,000 metric tons; and in South America from 97,000 to 219,000 metric tons.

The increased role of aquaculture around the world results not only from continuing demand for protein and anticipated increasing world demand for fishery products but from other developments as well, such as the limited sustainable supplies of wild stocks, the establishment by most nations of zones of extended national jurisdiction, increased harvesting costs, and sometimes the need to provide more employment opportunities. These developments, and continuing food crises, are expected to last to the end of the century.

Interestingly, the nations reporting soaring growth in aquaculture production lie at very different places along the continuum of technological innovation.

Chinese fish farmers, who have practiced aquaculture for millenia using simple and labor-intensive methods, have increased production of carp and other fish dramatically. Today, using new technology that includes more scientifically identified feed and the use of pumps to circulate the water, they have increased their yields as much as 20 times over those obtained from traditional earthen ponds. Such efforts by China to modernize its aquaculture industry are paying off handsomely. Since 1979, the harvest of aquaculture products has increased nearly 90 percent in the coastal waters and shoals under cultivation. The reported aquaculture harvest in 1984 of 2,450,000 metric tons was said to be about one-third of the country's total output of fish, shellfish, and seaweeds.

At the other end of the continuum in sophistication of aquaculture technology are nations like Norway, which has been concentrating very heavily on the growth of salmon and trout farming. So rapid has been the growth of salmon farming in Norway that it is predicted that as early as this year—or 1986—salmon and trout—rather than cod—will be the biggest money earners in the country's fishing industry. This would mean that the most valuable fish in Western Europe's top fishing nation are products of aquaculture. According to the March 1985 issue of Fish Farming International, the Norwegians have again raised their already optimistic forecasts of the production of salmon and trout through farming from nearly 26,000 metric tons in 1984 to 70,000–80,000 tons by 1990. Many farms are now being enlarged and about 100 new concessions to farms were granted in 1984. The Export Council of Norway, commenting on the doubling this year of state funding for aquaculture research and development, says that forecasts "already suggest that Norway could be producing 200,000 tons of high quality farmed salmon and trout by the end of the century, a 10-fold increase on present output." Norwegian salmon farming expertise is also becoming a valuable export: Norwegian companies are setting up subsidiaries in France and the United Kingdom, with trial operations in progress in Tasmania and certain Third World countries.

Incidentally, the United States is Norway's fastest growing market for salmon. Five years ago Norway introduced fresh farmed Atlantic salmon into the U.S. market. By 1983, Norway was exporting nearly 4 million pounds to the United States, and in 1984 that figure more than doubled. Meanwhile almost every country in northern Europe, as well as Canada, Chile, New Zealand, and the United States, has begun to try to emulate Norway's success with pen-reared salmon.

Much of the scientific knowledge on which Norwegian success rests was generated by Canadian scientists. Now the Canadian Government is realizing that the potential of aquaculture remains largely unrecognized in Canada. The Science Council of Canada has predicted that developing an integrated aquaculture industry in Canada would yield significant economic benefits within 10 years and has urged Investment Canada to seek out domestic and foreign capital to stimulate development of Canadian aquaculture. In a statement entitled "Aquaculture: An Opportunity for Canadians," the Science Council argues that aquaculture is on the threshold of commercial development. However, the Council warns that Canadians must quickly adopt, adapt, and develop the necessary techniques for a viable aquaculture industry before the window on market opportunities closes. The Science Council also encourages the industry to seize opportunities for technology transfer and develop new markets for species under commercial production in Canada. It further urges governments to reorder their investment incentives to attract Canadian capital into promising new areas of knowledge intensive development, such as aquaculture.

As fully described in Gerald Bowden's book, "Coastal Aquaculture Law and Policy: A Case Study of California," aquaculture in the United States has never reached its full potential, for reasons judged to be geographical, economic, legal, institutional, and sociological rather than scientific or technical. Aquaculture is nonetheless a dynamic and growing segment of the American economy—one that offers an excellent opportunity to improve our balance of trade. The National Marine Fisheries Service estimates that private aquaculture firms in the United States account for the production of 40 percent of the Nation's oysters and the majority of catfish, crawfish, and trout. Estimated U.S. private aquaculture production for 1982 was 179,465 metric tons, representing about 11 percent of the total harvest of edible fish and shellfish in this country.

In the United States the increasing cost of labor and feed alone has forced adoption of advanced culture methods leading to increased yield, methods which are in turn based on scientific studies related to nutrition, physiology and behavior, production of seed stock, genetic selection and hybridization, and pathology. The United States is thus at the upper end of the continuum of technological innovation.

The editor of Aquaculture magazine has attributed recent U.S. growth in aquaculture to the type of technological progress being supported by Sea Grant. Specifically, she cites the work of a California Sea Grant research team headed by Dr. Daniel Morse of the University of California, Santa Barbara, which has developed biochemical and genetic procedures with important commercial applications to improve the spawning, larval development, metamorphosis, and growth of molluscs such as abalone. The procedures developed by this research team, she observes, "are increasing a hundred-fold the chances for financial success of companies engaged in shellfish culture." Dr. Morse's work demonstrates that although the application of results from biotechnological research is still in a very early state of development, available techniques can do much for the field of aquaculture, a point to which I shall return.

There has been a good deal of cooperation between the United States and Japan on advanced genetic and hormonal studies in aquaculture. For example, scientists at the University of California, Berkeley, and the Ocean Research Institute of Tokyo University have collaborated for some time on understanding the salmon smoltification process. The economic significance is considerable in that it is estimated that only 60 percent of the smolts reach the ocean in a viable state. Through this ongoing cooperative effort significant progress is being made in solving this very real problem through very basic scientific techniques. Another example of international cooperation is provided by the Washington Sea Grant Program. Scientists from 10 countries shared research results on how to improve reproduction to enhance stocks and hereby lower product costs worldwide.

At this point it might be appropriate to consider briefly the status of biotechnology worldwide. At present the United States is spending about $1.5 billion a year, from industry, Government, and the nonprofit sector, to develop the new techniques of biotechnology. I want to emphasize that I am speaking here about biotechnology in general, not marine biotechnology. Benefits in agriculture, health care, energy, pollution control, and the chemical industry are projected to be enormous. Though current sales of genetic engineering products are modest—an estimated $500 million in 1985—they are expected to climb to more than $100 billion by the year 2025.

Nowhere in the world today are efforts to commercialize biotechnology larger than in the United States. The U.S. Office of Technology Assessment has identified 219 companies in the United States for which commercial application areas in biotechnology are known—companies that range from the start-up biotechnology companies that took the lead, such as Genentech, to established giants like Exxon. California, with one-third of the Nation's biotechnology firms, stands at the forefront of this technology in the United States. This preeminence has been attributed by the California Assembly Office of Research in its 1985 report "Biotechology: A Regulatory Review," to (1) the strong research and leadership role played by California universities, and (2) the entrepreneurial/venture capital environment present in the State. Because biotechnology is still in an early state of commercial development, competition remains largely in research and early product development. U.S. competitive strength will be tested when large-scale production begins and bioprocessing problems are addressed. Challenges to the United States in current and future product markets will be made by established companies in the Federal Republic of Germany, United Kingdom, Switzerland, France, and especially, Japan—a nation frequently characterized as a prime competitor, but one with which we have what Ambassador Mike Mansfield has termed "the most important bilateral relationship in the world."

According to a report on commercial biotechnology by the U.S. Office of Technology Assessment, the Japanese consider biotechnology to be the last major technological revolution of this century, offering that nation an important opportunity to revitalize its structurally depressed basic industries whose production processes are reliant on imported petroleum. A report by the Japan Economic Research Center last year said that Japan could surpass the United States in biotechnology in the 21st century, largely through technical links and joint ventures such as that recently formed between Amgen, a 5-year-old California biotechnology firm which has developed a hormone used for treating anemia, and Kirin Brewery Co. Ltd., a giant Japanese beer manufacturer. "Venture enterprises in the United States have the technology to develop new products but not necessarily good production facilities or marketing ability," observed Shigetaka Seki of the Bioindustry Office of the Japanese Ministry of International Trade and Industry [MITI], Los Angeles Times, April 19, 1985. "So they link up with large chemical companies, both in the United States and in Japan." At least four Japanese firms are working with British and American firms on interferon research, for example.

In addition to joint ventures and technical linkages, Japanese companies contract out R&D work on a massive scale to U.S. universities, such as MIT, and to private U.S. research institutes.

And in Maryland, a Japanese biotechnology company, Otsuka Pharmaceutical Co. Ltd., has recently opened a research facility in Rockville, thus becoming the first Japanese company to build a biomedical research laboratory in the United States. One of the attractions of the area was obviously the newly created Center for Advanced Research in Biotechnology, being created jointly by the University of Maryland, Montgomery County, and the National Bureau of Standards.

Many U.S. biotechnology firms believe that the benefits of international financial and scientific cooperation outweigh the risks of net flow of biotechnology transfer outward from the United States. They are concerned, however, about unnecessarily restrictive regulations that, for example, prohibit export of high-technology products, thereby leaving the market open to international competition.

As to application of biotechnology to aquaculture, the U.S. Office of Technology Assessment has identified five major categories of biotechnology applications, including: (1) pharmaceuticals, (2) specialty chemicals, (3) environmental applications, (4) plant agriculture, and (5) animal agriculture. Of the 219 U.S. companies for whom commercial application areas are known, 62 percent are pursuing biotechnology applications in the area of pharmaceuticals, 28 percent in animal agriculture and 24 percent in plant agriculture.

As has been indicated in testimony here today, marine biotechnology is capable of significant contributions to each of these five major categories of biotechnology applications. It has already been demonstrated, for example, that genetic engineering and recombinant DNA techniques can eventually be applied to the creation of new and improved strains of many, if not all, of the existing and potential aquaculture species. Specifically, biotechnology can be used to produce organisms that grow faster, contain more meat and less waste, are disease resistant, are more efficient in food conversion, and have expanded ranges of temperature and salinity.

Indeed, it has been argued that aquatic organisms are better suited to genetic manipulation than are terrestrial species. The reason includes the fact that aquatic species have a higher degree of genetic variability than terrestrial species; fish and many cultivable invertebrates are notable for their remarkable fecundity; sex determination in fishes and aquatic invertebrates is more plastic and production of single-sex stocks through hormone treatments is easier; and offspring resulting from crosses between different species are often viable and even fertile in fishes and invertebrates. Last, and of great significance, is the fact that terrestrial plants and animals of importance to humans—like corn and cattle—have been subjected to at least a crude form of selective breeding and stock improvement over long periods of time. Aquaculture organisms, on the other hand, and with the exception of salmonid fishes, oysters, and certain seaweeds, are still in their native form.

The applicability of biotechnology could dramatically alter the profitability of commercial aquaculture. In addition, it offers the possibility of improving the ability of fish in natural waters to cope with their polluted or altered environment. As Dr. David Attaway of the National Sea Grant College Program has observed: "Only a few exploratory projects along these lines have been undertaken so far with marine species. Workable methods and technology will develop slowly unless greater research effort is applied."

As to the application of biotechnology to marine pharmaceuticals, the first applications of biotechnology have emerged in the area of pharmaceuticals, a research-intensive industry that the Office of Technology Assessment predicts will be "the first and perhaps most intense proving ground for U.S. competitive strength in biotechnology."

Over the last 20 years, the majority of new drugs have been developed by the American pharmaceutical industry or their subsidiaries in Europe. The Japanese industry (the world's second largest after the United States) now accounts for about 20 percent of all new drug products in the world compared with no more than 1 percent a decade ago—though most products represent improvements on existing drugs rather than breakthroughs.

Breakthroughs are however possible from the pharmaceutical applications of biotechnology, an area being vigorously investigated by biomedical scientists in the United States, Japan and Europe. Japan is particularly interested in producing anticancer drugs using monoclonal antibody techniques.

It is noteworthy that some major U.S. drug companies have started major cancer research organizations outside the United States—in France, Germany, and Japan, for example. This phenomenon is a result of the intensity of labor needed, the availability of high-technology labor, and variations in Government regulations on introducing drugs to the marketplace. Using biotechnology, drugs can be produced using cloned genes or applications of recombinant DNA technology.

Perhaps more importantly, the new biotechnology provides a means of producing large amounts of compounds that are otherwise scarce. One example is provided by the marine pharmaceutical compound called manoalide—presently being collected from a sponge found off Palau, an island in the Pacific. Discovered by a California Sea Grant research team, manoalide has proved to be a model for a whole new class of nonsteroidal, anti-inflammatory drugs. Culturing of marine invertebrates and their symbionts, such as bacteria and algae, using recombinant DNA and monoclonal antibody techniques would allow us to produce large amounts of drugs that are presently very costly to synthesize or that exist only in small amounts or in rare species. It is also possible that some other more easily cultured kinds of animals or plants could be bioengineered to produce these drugs.

The first major effort in the area of isolating potential pharmaceuticals from marine plants and animals was made by Hoffman-La Roche, the Swiss drug company, which in 1974 established the Roche Research Institute of Marine Pharmacology near Sydney, Australia. The laboratory closed in 1980 when the company changed its research emphasis.

Today the United States—largely through projects funded by Sea Grant—and Japan are showing growing interest in obtaining drugs from the sea—compounds with antifertility, anticancer, and anti-inflammatory properties, for example. It should be noted that a large proportion of the bioactive compounds found in marine organisms possess unusual and generally unprecedented organic structures, which provide significant leads to new drugs with novel mechanisms of action.

Stypoldione, a marine cytotoxin extracted from seaweed, was discovered during investigations by the same California Sea Grant research team that identified monoalide. Cytotoxins, as their name suggests, are compounds that kill cells. The drug vincristine, for example—a natural drug derived from a terrestrial plant—is a cytotoxin used in cancer chemotherapy.

Stypoldione, currently being evaluated at the laboratories of Eli Lilly as an anticancer agent, has shown cytotoxicity against several human neoplastic cell lines in in vitro and in vivo culture. And testing at the National Cancer Institute has shown that the compound is effective against a specific kind of leukemia in the mouse. Its mechanism of action—that is, the way it inhibits cell division—is slightly different from, and is complementary to, the mechanism of action of vincristine. Hence, stypoldione has promise as an anticancer drug used in conjunction with other drugs. It is hoped that, using the techniques of biotechnology, researchers will be able to add an antibody to stypoldione that will cause it to bind to a specific cancer protein, ultimately killing the cancer cell.

Because it inhibits cell division, stypoldione is potentially useful in treating other kinds of diseases characterized by growing cells; for example, it could be used against human diseases caused by parasitic infections, such as schistosomiasis.

Lophotoxin, a marine cytotoxin isolated from various species of the Pacific sea whip, causes potent and irreversible blockage of neuromuscular transmissions in much the same way as do snake venoms, leading to irreversible paralysis and death. Theoretically, one could selectively target any deadly toxin like lophotoxin to various specific surface proteins—those produced by one particular insect or animal species or a particular race or group of people, for example. What we are talking about here is a highly selective kind of targeting—the selective delivery of potent toxic chemicals.

The pharmaceuticals market, one of the most successful high-technology sections of the world economy, is enormous: Now an estimated $80 to $100 billion a year. The U.S. market, the world's largest, is an estimated $20 billion; the Japanese market is second at an estimated $13 to $16 billion. Industry analysts suggest that developing Asia, where sales of pharmaceutical products are growing at a fast pace, and projections are for even higher growth rates, will overtake Japan by the year 2000 to become the second largest market. In the poorer countries there are enormous possibilities for expansion of cheaper and common disease-combating drugs.

As to research in marine biotechnology, you have already heard described in other testimony here today, some of the research efforts in marine biotechnology that are underway in the United States. Let me now describe for you some of the efforts being conducted elsewhere in the world; for though the U.S. holds a significant advantage in biotechnology, those nations which are both exploiting the fruits of the sea and which are technologically advanced are well aware of the strategic and commercial potential of marine biotechnology.

One of the pioneers in the field of salmon growth control, sex alteration, and chromosome set manipulation is Edward M. Donaldson of the West Vancouver Laboratory, an installation of Canada's Department of Fisheries and Oceans. Among numerous studies, Donaldson and his colleagues are using androgen hormone treatments to turn genotypically female salmon into functional males, but males who then produce only female offspring when mated with normal females. This is important because female salmon are more highly valued than males—not only do they produce eggs, but their meat retains desirable qualities longer.

The Japanese are also doing very sophisticated work on chromosomal engineering, using the technique described above, for example, with rainbow trout to create female stocks. Conversely, hormones can be used to create male stocks.

An example of the commercial application of such genetic engineering was provided at the recent Second International Symposium on Genetics in Aquaculture held at the University of California, Davis, where it was reported that trout production in the United Kingdom is now composed of 50 percent sterile female triploids; in the United States it is zero percent.

Donaldson has also resumed his work with growth hormones and salmon—work he abandoned in the 1970's because of the then-prohibitive cost of the hormones. Now, in preliminary work using much-less-expensive recombinant chick growth hormone, he and his colleagues have been able to demonstrate a two-fold increase in growth, at least in young fish that are still undergoing treatment. Donaldson believes that if hormone treatment can double or triple the size of the salmon when they are released, it could double or triple the percentage of salmon that return. If biotechnology procedures can be developed for the natural incorporation of excessive growth hormones, this will provide a product that has not been fed external hormones, hereby eliminating consumer concerns.

I mentioned earlier the enormous success being enjoyed by the Norwegians in producing farmed salmon and trout. Among recent research achievements in this area, the Norwegians are reported to have mastered the technique of cloning female fish from roe, with a 70 percent yield. This means that from a female fish 7,000 identical copies can be produced through spawning.

At Clearwater Trout Limited on the Isle of Man, United Kingdom—one of the forerunners in the egg-producing farms for the international rainbow trout industry—a technique is being developed for rearing sterile trout whose chromosome count is triploid, and where little or none of the energy required for growth is diverted to gonadal development.

The Institute of Aquaculture in Stirling, Scotland, is evaluating some of the culture characteristics of hybrid tilapia strains, including growth rate, flesh yield, disease tolerance, and salinity tolerance—Tilapia, a tropical species has been described as being potentially the world's most important cultured group of fish—of particular interest is the genetic basis for sex. If all-male tilapia cultures could be grown, this would eliminate the overbreeding problems which plagued simple pond culture of mixed sexes in Africa, for example. More sophisticated techniques such as shock-induced polyploidy for producing fast-growing sterile fish are also being investigated.

Marine algae are also well suited to genetic manipulation. Many commercially important seaweeds have a complex alternation of generations between a haploid sexual plant stage and a diploid asexual generation. Chinese scientists have found that such characteristics as length, iodine content and growth rate in the kelp *Laminaria japonica*—an important source in Asia of food and algin—are controlled by a single gene or by quantitative polygene inheritance patterns. Increased yields have resulted from selective breeding of the kelp, and its range has been extended much farther south than the species normally occurs.

J.P. van der Meer of the Atlantic Research Laboratory in Nova Scotia has investigated the genetics of the red algae—*Gracilaria tikvahiae*, a species that spontaneously produces many mutants and that can be chemically induced to produce hundreds more, most of which show recessive, single-gene transmission characteristics. This species does contain the valuable polysaccharide agar, which, if contained in higher quantities in mutant strains than in the normal parent stock, could be of economic interest.

A Florida firm, Petroform Inc., is commercializing an oil-emulsifying biodetergent developed by three Tel Aviv University researchers. The biodetergent, named Emulsan, was first isolated from a marine bacterium in the mid-1970s. Emulsan will be used in enhanced oil recovery and pollution control.

Australia has been working hard to catch up with U.S. and Israeli scientists who are studying genetic manipulation of algae to enhance production of byproducts.

Scientists at the Westfarmers Algal Biotechnology Pty. Ltd. in Perth have been completing a feasibility study with government funding to determine whether algae-produced commodities can compete with synthetic equivalents. Their conclusion is that such commodities can compete if scientists develop expensive chemicals in high international demand, such as carotenoids, which can fetch up to $1,000 per kilogram. Scientists at the Westfarmers facility will concentrate on the prolific single-celled green algae, *Dunaliella salina,* which appears red as a result of its high beta-carotene content. The carotene can be converted into vitamin A or used as natural food colorings to improve color in orange juice, margarine or egg yolks.

Other countries are also moving into microalgal biotechnology. In France, the Association for Research in Solar Biology (St. Paul-lez-Durance) is evaluating the microalgal production of hydrocarbons and polysaccharides. Eight percent of the association's research is funded by the French Government and 20 percent by a consortium of industrial companies.

Dr. Maxwell Doty of the University of Hawaii estimates that worldwide over 200 present products, such as lotions, beer, ice cream, and pastry frostings, as well as medical and industrial uses, amount to $20 billion of final sales each year. In the United States, Kelco Corp. of San Diego, CA produces the agar, carrageenan, and colloids that are used in such products from wild algae stock. U.S. emphasis on production of these useful marine products should continue to be stressed over production of raw material products, which the Japanese and Chinese do extremely well.

What these examples strongly underscore is that the commercial viability of aquaculture depends heavily on scientific and technical information about the organisms being cultured. Today, though there is still an enormous amount of research to be conducted in what may be termed conventional biological problems, many marine organisms can be cultured successfully throughout their life cycle. Increasing the productivity of the processes is what is now needed. Therefore, the greatest technological potential for aquaculture today is based on developing breeding techniques—as mentioned earlier, little work has been done to improve genetic qualities even in the most studied species. With regard to such applications as pharmaceuticals and bioproducts, industrial chemicals, biodegradants and biofoulants, to choose just a few examples, the economic potential of the new biotechnology cannot even be estimated. Yet we are approaching a most difficult and sophisticated set of problems and opportunities with a bargain-basement mentality.

In conclusion, it is clear from what has been discussed that the United States is preeminent in biotechnology research and commercialization, as well as in the subcategory we have considered here today, marine biotechnology. Though we are ahead generally speaking, this is not true of all areas. For example, Japan leads the world both in the microbial production of amino acids and in large-scale plant culture, and it is strong in the new antibiotic product markets. It is also considered the world leader in traditional bioprocess engineering. Speaking generally, I would venture to rank the United States first in marine biotechnology development, followed by Japan and then Europe at the present.

Since biotechnology does not describe a single procedure or process but instead encompasses a diversity of means for using biological systems to develop useful products, we presumably can make some choices. Because the technologies are still emerging, and because most marine biotechnology products and processes are in early development, we should accelerate the development of a range of options from which to choose new growth industries.

The OTA in its comprehensive report, "Commercial Biotechnology: An International Analysis", focused on factors that would need broad consideration in determining the future international competitive position of the United States vis-a-vis other countries with respect to the commercialization of biotechnology. In their analysis, emphasis was placed on competitive forces in five countries in addition to the United States: Japan, the Federal Republic of Germany, the United Kingdom, Switzerland, and France.

The following 10 factors were identified by OTA as potentially important in determining the future competitive position of the United States and the other countries: Financing and tax incentives for firms; government funding of basic and applied research; personnel availability and training; health, safety, and environmental regulation; intellectual property law; university/industry relationships; antitrust law; international technology transfer, investment and trade; government targeting policies in biotechnology; and public perception.

Of these, the three factors judged most important by OTA to the commercial development of biotechnology are: First financing and tax incentives for firms; second, government funding of basic and applied research; and third, personnel availability and training. I have no quarrel with the fact that OTA ranked these three factors high.

However, my own analysis with respect to the United States suggests that two items that the OTA ranked low—in fact at the bottom—are critical to improving our international competitiveness and should be elevated in ranking of importance: the first of these is public perception.

In a democracy, public perception is critical and should be ranked first. In a recent editorial in BioScience, Harvey Price, executive director of the Industrial Biotechnology Associations, observes:

> Companies that are now or will be offering products developed through biotechnology are naturally concerned about public acceptance and its impact on public policy decisions. To the extent that public perception translates into public policy, our national commitment to pursuing the commercialization of biotechnology may be in some peril if ignorance engenders fear of biotechnological research and applications.

Japanese organizations unlike our own have, as Ezra Vogel observes in his latest book, "Comeback":

> Done a superior job of positioning themselves in organization, information, research and education to prepare for tomorrow's opportunities. Our ability to respond to the new international competitive environment is the paramount problem of our generation.

Vogel further observes:

> Except for a national emergency . . . no issue is as likely to have such an impact on Americans' daily lives and the national spirit. We would be unwise not to give it the sustained public attention it deserves.

The other factor ranked low by OTA, which I would elevate to second place, is developing government targeting policies to identify and acelerate growth of new industries. The idea of selective industrial targeting, common in other developed countries, may seem highly unusual to many here. However, our history contains many cases. For example, in an earlier period of economic growth and development of this country, we targeted the railroads for accelerated growth via massive government grants of land. Another example is housing, targeted after World War II for growth through tax and finance incentives.

The tools needed to facilitate the successful implementation of a targeting policy, in addition to tax and finance packages, are: Realistic health, safety, environmental and export regulations; a user friendly, or flexible bureaucracy; a responsive, coordinated, government/industry/academic infrastructure; well-framed laws; and training and retraining programs to provide necessary specialists. The infrastructure I refer to should contain mechanisms able to identify the international competitive impact of proposed governmental actions—for example, deregulation as well as regulation—areas of needed research, facility needs, and the like. Another critical component is the provision of properly educated and trained specialists to staff the key elements of the infrastructure. Here, of course, our Sea Grant Colleges can play a central role, in addition to conducting marine biotechnology research. In short, I am talking about the steps necessary for the successful research, development and commercialization of marine technology, to use Vogel's terminology.

There is also a point I would like to make with regard to one of the 10 factors of potential importance that the OTA places high on the list of importance: government funding of basic and applied research. One component of the research continuum conspicuous because of the relatively small financial commitment made by the United States is generic research—generic applied science—in OTA terminology. Generic science is the traditional bridge between basic, or fundamental, scientific inquiry—the traditional domain of the university—and applied research the domain of industrial laboratories. Generic research is designed to solve general problems associated with the use of a particular industry. Examples of this type of research in biotechnology are development of bioreactors, screening of microorganisms for potential products, and better understanding of the genetics and biochemistry of industrially important marine microorganisms. Concludes the OTA:

> In fiscal year 1983, the Federal Government spent $511 million on basic biotechnology research compared to $6.4 million on generic applied research in biotechnology. The relatively low level of U.S. Government funding for generic applied research in biotechnology may cause a bottleneck in this country's biotechnology commercialization efforts.

I am concerned that this critical link in the research chain is overlooked by the Office of Science and Technology Policy, which seems consistently to divide research into basic and applied. And, of course, the dollar figures for research quoted above support this concern as a most serious one.

In closing, I would like to relate to you a statement made by the late John D. Isaacs, director of the University of California Institute of Marine Resources, on the occasion of the founding of the marine products research group 10 years ago:

An entire new universe of pharmaceuticals may be discoverable in the sea, complementing and even exceeding the contributions of tha vast array of active substances mankind has learned to elaborate by centuries of investigation of the plants and animals of the land.

Thank you, Madam Chairwoman, for the opportunity to appear here today, and I commend the committee for bringing these important matters to the national policy level. I am available to answer any questions you may have.

[The attachment to Dr. Sullivan's statement follows:]

UNIVERSITY OF CALIFORNIA BIOTECHNOLOGY RESEARCH AND EDUCATION PROGRAM

I. INTRODUCTION

Biotechnology, broadly defined, includes any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses. During the past ten years, significant advances in genetic research have led to the development of techniques which have exciting and valuable applications in such areas as pharmaceuticals, plant and animal agriculture, specialty chemicals, and the environment. Recombinant DNA technology, which allows the direct manipulation of the genetic material of individual cells, has been used to produce insulin and interferon, and may potentially be used to produce micro-organisms that degrade toxic wastes. Cell fusion, which combines the desirable characteristics of different types of cells into one cell by artifically joining them, can be used for the diagnosis and treatment of disease and the purification of proteins. Bioprocess engineering, which allows the adaptation of these biological methods of production to large scale industrial use, has furthered the commercialization of biotechnology by increasing production and facilitating recovery of many substances.

These dramatic developments in biotechnology have had a major impact on the biological sciences. By revolutionizing approaches to fundamental biological problems, they have significantly altered the scope of the field. In addition, they have given rise to a new industry consisting of biotechnology companies using this new knowledge and those new techniques to produce substances of great importance to medicine, agriculture, and industry.

California is currently at the forefront of the biotechnology endeavor—much leading research performed in the nation occurs on University of California campuses and approximately one third of the biotechnology firms in the nation are in California—yet this lead is a tenuous one. University, industry, and government representatives have all acknowledged the serious shortages in resources available for both basic research and training of graduate students and other professionals. They have stressed that funding of these areas is necessary to insure the viability and competitiveness of California's biotechnology industry, both at home and abroad.

Competition for development in this area is considerable. Many states have aggressively responded to research and training needs by establishing programs and centers which encourage collaborative biotechnology research efforts between industry and university scientists. The oldest such effort is the North Carolina Biotechnology Center, located in Research Triangle Park, which has been followed by a number of other state-funded institutes, such as the Molecular Biology Institute in Michigan.

The University of California has recognized the magnitude of unmet needs in biotechnology related programs, which range from insufficient expertise and research in the area of bioprocess engineering, to inadequate laboratory space and equipment, to shortages in qualified faculty members who can undertake new research and teach students at all levels. As a first step in a multi-year effort aimed at addressing these needs, the University is establishing the Biotechnology Research and Education Program. The program will focus on facilitating multidisciplinary basic research at the forefront of the field for the purpose of training future scientists and promoting further development of the biotechnology industry in California.

II. ELEMENTS OF THE PROGRAM

The program, which is University-wide, will consist of three major elements: (1) research and related needs; (2) education and training; and (3) information exchange with government, industry, and the public concerning biotechnology developments in the University, the State and elsewhere. The first two elements will be combined through the support of proposals from campuses or between campuses and the University-managed Department of Energy (DOE) Laboratories (LBL, LLNL, LANL) that both further significant research and assure training of graduate students and post doctoral fellows. The third element of the program, that of information exchange, will be coordinated by the Office of the Director. This office will, among other things, keep abreast of the ongoing information exchange efforts of the campuses and DOE Laboratories. The program will be under the overall authority of an Executive Committee and Director, who will be assisted by an Advisory Committee representing outside interests.

For purposes of this program, biotechnology is defined broadly as "any technique that uses living organisms (or parts of organisms) to make or modify products, to improve plants or animals, or to develop micro-organisms for specific uses." [1] Current techniques include recombinant DNA, cell fusion, and bioprocess technology.

A. Research and Related Needs.—The program will support major biotechnology research initiatives. The crucial importance of such innovative research has been recognized in all areas where biotechnology techniques are being used, including among others, medicine, agriculture, marine biology, and biochemical engineering. In agriculture, for example, new technologies involving recombinant DNA and other genetic engineering techniques offer immense promise in achieving the agricultural breakthroughs that California farming will require to meet increasing demands in the next fifty years. In the area of biochemical engineering, which focuses on the large scale manufacture and purification of biological products, new research developments are vital if the U.S. biotechnology industry is to maintain a competitive stature.

The following categories provide an indication of the general areas of biotechnology research that will be supported by this probram. Proposals may also represent research cutting across these categories, for example a project that combines the development of insect resistant plants (agriculture) with the development of methods for measuring the impact of introducing such plants into the environment (policy and ethical issues).

Biomedical Research—The area of biomedical research reflects an overlap of fundamental molecular genetics, cell biology, immunology, biochemistry, neurosciences, and developmental biology. It includes the use of biotechnology to diagnose and treat diseases more effectively as well as to develop new pharmaceuticals for both human and veterinary use.

Agricultural Research—Biotechnology in agriculture includes research on improving the yield and quality of both animal and plant products, on developing more effective means of pest control, and on studying soil systems.

Environmental Research—Related to agricultural developments are environmental applications of biotechnology research which address problems of increasing salinity, toxic substances and high concentrations of heavy metals in soil. Environmental applications focus on developing methods to treat liquid and solid wastes, to leach minerals and to clean up oil spills.

Marine Biotechnology Research—Marine biotechnology is a rapidly growing area of research, which utilizes the advances in genetic manipulation to improve the production of food and other resources from the ocean and to develop new products from marine organisms.

Biochemical Engineering and Instrumentation—This research focuses on developing effective methods for the large scale production of products developed through genetic manipulation, including for example, fermentation technology and process recovery.

Policy and Ethical Issues in Biotechnology—The advent of new techniques in biotechnology has had a major impact on social and ethical issues. This area of research addresses regulatory issues and the policy and ethical implications of biotechnology research.

B. Education and Training.—The most critical need of new and established biotechnology firms is a qualified labor force at all levels of employment. Graduate students and post doctoral and industry fellows need training in and exposure to the most current and sophisticated techniques and equipment. The seriousness of this problem has been made clear by State and Federal legislative hearings and by reports prepared by governmental agencies and other organizations, including the National Research Council (NRC) of the National Academy of Sciences and the National Association of State Universities and Land Grant Colleges (NASULGC). For example, the NRC estimates that during the next decade, the annual need for graduate-level biochemical engineers will average two to three times the number currently being trained, which is approximately sixty per year.

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[1] Commercial Biotechnology: An International Analysis (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-BA-218, January 1984.)

Training at the graduate and post doctoral level is also vitally important to the academic community. During the past few years, university campuses have had difficulty in competing with industry to hire outstanding young scientists and have lost faculty members to biotechnology firms. In addition, the demand for biotechnology related classes and majors has been growing rapidly among undergraduate students. A highly qualified university-level workforce is necessary to undertake future basic research that will provide the foundation for commercial developments in biotechnology.

Currently, the resources available for training these students are insufficient. Nearly all of the University's campuses must turn away a large percentage of qualified applicants each year. At UCSF, for example, in 11 graduate programs where biotechnology research is conducted only 18% of the 500 qualified applicants could be accepted in 1983–84. At Los Angeles, only 85 of 220 qualified applicants (38%) could be accepted during this time period, meaning that the campus had to turn away two students and post doctoral fellows for each one accepted. Accordingly, a large portion of funds for the program will be used to support such students as they undertake new multidisciplinary research efforts under the direction of established faculty members. This education and training part of the program is to be included as an integral component to the research part. In selecting projects for funding, emphasis will be placed on areas of research and training where there are perceived shortages. Currently, needs are most pressing in the areas of plant molecular biology and biochemical engineering.

C. Information Exchange with the Public.—The program will provide a channel of communication with government, industry and other important constituencies regarding issues vital to biotechnology in California. Representatives from these groups will be included on the Advisory Committee. The program will disseminate information to the public regarding research developments in biotechnology through written materials as well as seminars and workshops. Facilitating interactions with industry through these means and other cooperative programs will enhance technology transfer.

III. MANAGEMENT OF THE PROGRAM

A. Executive Committee.—The Program will be managed by an Executive Committee appointed by the President of the University, comprised of one representative from each campus and from each of the University's Department of Energy Laboratories. The Program Director will chair this Committee. The specific responsibilities of the Executive Committee include setting the priorities of the program and establishing criteria for the funding of proposals. The Executive Committee will establish a process for peer review and selection of proposals for funding.

B. Program Director.—The Director, who must be a tenured member of the faculty, will have overall responsibility for the program on a day-to-day basis and will be assisted by an administrative staff. The Director will chair and convene the Executive and Advisory Committees and will be responsible for the information exchange elements of the program. In this role, the Director will be the principal link between the program and key outside groups and individuals. Finally, the Director will work closely with the major representatives from campus and Laboratory projects that are being funded.

C. Advisory Committee.—The program will include an Advisory Committee appointed by the President in consultation with the Executive Committee, which will consist of representatives from the California biotechnology industry as well as from related State agencies and environmental organizations. This Committee will advise the Executive Committee about the overall research and training direction of the program and will provide information about the business and regulatory environment in the State. It will also be an important liaison with State agencies and legislators who are concerned with biotechnology.

IV. PROPOSAL SUBMISSION AND BUDGETARY ISSUES

Each campus and Laboratory will be invited to submit a single proposal each year to the Executive Committee that combines the research and education functions. DOE Laboratory proposals should include major collaboration with one or more University campuses. Each year the program will allocate funds to selected projects (multi-year projects will be awarded a lump sum in the first year to cover the duration of the project as proposed).

During the first year of the program, it is proposed that approximately 3 or 4 research projects be funded at the level of $300,000-$500,000 each, for a total expenditure of $1,350,000 on this portion of the program. Each of these projects will be a multidisciplinary effort on a campus or between campuses and Laboratories. Each project will allocate the funds awarded for graduate student and post doctoral fellow training, specialized research equipment, and technical support staff. It is expected that supply funds for the project will be provided by other sources. The proposed funding for the Office of the Director for the first year is $150,000, which includes support of the Director up to 0.5 FTE and provides for staff and office expenses as well as for the information exchange aspects of the program. The host campus will be expected to provide space and other necessary support.

It is expected that this $1.5 million first year's budget will be substantially increased in future years, once the program is in place, to respond to the needs for research and training in this area.

Ms. **Mikulski**. Thank you very much.

Pertaining to the U.S. research, you said that the Federal Government spent $511 million on basic biotech. Yet we heard Sea Grant spent $8 million on marine biotech. Where was the other $503 million spent?

Dr. **Sullivan**. This was not spent in the marine area, but for basic research in biotechnology. U.S. Government agencies funding research in the biotechnology are NIH, NSF, USDA, DOE, and DOD.

Aside from Sea Grant, probably the only other Federal agency making a sustained contribution in the area of marine biotechnology is the Office of Naval Research. It is interested principally in military uses such as antifouling.

Ms. **Mikulski**. Dr. Sullivan, you heard me raise earlier the issue of a national clearinghouse on biotechnology. Is it your perception of the Federal Government that we do not have a clear national goal? We had a national goal related to space that drove us for 20 years to dazzling achievements. Is it your perception that we have a clear national goal for what we would like to achieve in biotechnology, and a clear and coordinated method for achieving that goal? Do you think we need it?

Dr. **Sullivan**. I think we need a clear perception of where this country wants to go in the areas of biotechnology in general and marine biotechnology in particular. I do not think we really have a clearly spelled-out goal yet. Proceedings such as this will help form that goal.

As far as a clearinghouse, the newly established National Science Foundation Office of Biological Coordination, and as was mentioned earlier, the White House Interagency Council are looking at biotechnology. There have probably been three levels at which information is coordinated so proper policy can be made.

Ms. **Mikulski**. One last question. I was glad to see you raise the issue of personnel, which is essentially who paid for your Ph.D., and I am not talking about a political economist, but we do need scientists in this country. I happen to believe that the benefits of an education accrue not only to the individual but to society as a whole. I have a master's degree in social work which was partially paid for by the National Institutes of Mental Health. Whether I have ultimately contributed to the mental health of the country is debatable and would provoke the most lively debate on the committee, but one wonders where our scientists are being trained.

Would you elaborate on your personal aspects?

Dr. **Sullivan**. I had principally two sources of financing. The main one was called the National Defense Education Act (NDEA). I was fortunate enough to be awarded an NDEA fellowship to attend the Johns Hopkins University. I received from Hopkins University a tuition remission fellowship so I did not have to pay the fees associated with attending the university.

As far as the need for personnel, let me give you an example of what has been happening the last few years in my own program. Four years ago, with basically the same funding we have now, we were supporting in California 72 graduate trainees. A graduate trainee is associated with one of our research projects. The reason we setup the traineeships is so students learn not only their fundamental discipline—biochemistry or chemical engineering, for example—but also how to apply that discipline to a contemporary scientific or technological problem by working with one of the Sea Grant Programs.

Today we are funding only 50 graduate trainees. We are down almost 30 percent, just in a matter of a few years, and that could be used as an example of what has been happening in many of the Sea Grant Programs across the country. We read newspaper articles describing what is happening to a numbr of Education Aid Programs for students and we see articles on the next page describing the continuing rise in the cost of education. So I think we do have a problem; and all the equipment in the world is not going to do us one bit of good without the trained personnel to use it.

Ms. **Mikulski**. Mr. Shumway.

Mr. **Shumway**. Thank you.

Dr. Sullivan, you mentioned that a decade ago we had a substantial lead among the nations of the world in developing this technology and we still have a lead but not as much as we had before.

In earlier testimony Dr. Karuna-Karan testified about the availability of venture capital, and he likened it to a herd. In 1978 and 1979 it was there and then the herd changed directions. Have we lost some of that lead because capital is not there as much as it was before?

Dr. **Sullivan**. The herd instinct, as we heard it referred to earlier, reflects the initial rush into an area where there is the potential for enormous profit from a relatively small investment, by people who are willing to take very, very high risks. As soon as that risk factor declines, it usually means that the immediate or high profit potential is declining somewhat as well. It would not be unusual to see the venture capitalists then switch to an area that offers a greater potential for return. After the venture capitalists have moved on, you then see the more traditional sources of capital move in, those that look for a less risky, more long term sustained rate of return on their investment.

Another factor, I think, is that other countries are recognizing the potential of marine biotechnology and are making increasing investments from a societal point of view in basic research and in generic applied research and in the training of personnel to staff the facilities.

Mr. **Shumway**. So if we had then the same kind of capital that we may have had in the 1970's, if we had the public perception that you talk about, if we had the Government targeting or the selection process you described, do you think we would clearly regain the edge we have had in the past over other nations?

Dr. **SULLIVAN**. There is nothing new to our pulling together in the sense that you are describing. At various times in the past, people from different sectors have pulled together when it was critical to do so. We would regain the ground we have lost and there is the strong potential that we could even move further ahead; but I am not sure we could do that in all areas. We might have to pick and choose a few areas that we want this country to lead in in the future, and that would be a difficult policy issue.

Mr. **SHUMWAY**. One problem I have in this area because it is such a new area and still a changing area, with reference to targeting by the Government or Government selection, how do we define where we want to go? We do not know what the ultimate end of all of this research may be. We are still learning and applying things in our laboratories. I do not know how we would set out to say we want biotechnology to provide all of the medicines of the future, revolutionize agriculture or provide the Nation's defense or whatever it may be.

It is easy to talk about Government definitions in that regard, but when it comes down to actually putting them in writing, as we must do when we enact laws, it becomes a difficult process. Do you agree with that?

Dr. **SULLIVAN**. Absolutely, I agree. Much more discussion is needed of where we want to go. For example, the academic community could bring to such a discussion potential dreams of what we might be able to discover or do, even some cautions about what directions we may not want to go in, for reasons we heard about today, namely possible, side effects. The industrial sector could bring to that type of discussion what they think has a potential for marketing, what they think will be of value. The Government sector could bring the ability to effect laws, regulations, and institutions.

Mr. **SHUMWAY**. It is more than defining, but the Government putting itself in the role of a coordinator, bringing all of these forces together to produce a solid effort?

Dr. **SULLIVAN**. A facilitator might be an excellent term for that.

Mr. **SHUMWAY**. Among the applications for Sea Grant funds that are made from your State, have you noticed increasing emphasis being given to this matter of marine biotechnology? Are more and more schools expressing an interest in wanting to get research for this area?

Dr. **SULLIVAN**. Yes, sir, in fact, during our most recent review cycle which we went through with relatively level funding we initiated three new marine biotech projects in addition to the ones we already have going on.

Ms. **MIKULSKI**. Dr. Sullivan, we thank you for your testimony. We hope you join us for lunch. Hopkins obviously did a very good job with you. Thank you for your testimony.

We would like to call for a briefing on some of the preliminary work done in the area of regulation by Dr. Anthony Robbins, a professional staff member.

[Briefing by Dr. Robbins off the record.]

[Whereupon, at 12:45 p.m., the committee adjourned.]

[The following was received for the record:]

THE UNIVERSITY OF MARYLAND

Center Of Marine Biotechnology

A Task Force Report

EXECUTIVE SUMMARY

The Center of Marine Biotechnology (COMB) within the University of Maryland Biotechnology Institute was established after intensive investigation into existing and potential resources in Baltimore and the surrounding area. COMB places the University of Maryland in a leadership role in the U.S. in the area of marine biotechnology.

The Center is dedicated to achieving excellence in research and education in marine biotechnology. The program carried out by COMB scientists is an interactive program in marine biotechnology, based on applied and basic research, with service to industry, government, and other institutions.

Priority research areas designated for the Center include:

Fisheries Enhancement, Management and Production

- Genetic engineering of commercially important marine organisms
- Determination of genetic structure and origins of fish populations and subpopulations
- Development of vaccines to protect cultured fish
- Determination of marine vertebrate immune mechanisms

Marine Materials and Specialty Compounds

- Determination of pathways of compound production
- Development of production approaches
- Development of biopolymers such as adhesives and surfactants for marine systems
- Development of food additives such as xanthans and carrageenans

Management of Wastes in the Marine Environment and Environmental Health

- Development of innovative approaches to pathogen control
- Development and improvement of biologically based methods for treatment of domestic and industrial wastes in the marine environment
- Determination of modes of action of marine toxins and pathogens
- Enhancement of processes that aid natural biodegradation processes
- Identification of biological indicators that predict environmental stress

Methods Development and Improvement

- Development of vectors for gene cloning in marine systems
- Development of techniques for the identification of marine pathogens
- Development of tissue culture systems for marine animals and plants
- Development of homozygous strains of marine organisms
- Improvement of methods--such as diagnostics--applied to fish pathology and disease

Marine Pharmaceuticals

- Development of screening techniques for potential marine pharmaceuticals
- Development of methods for producing promising marine pharmacological agents
- Determination of genetic origins of chemical production

- Evaluation of the potential of deep sea organisms for medicines

Special Applications

- Investigation of processes in biofouling
- Study of biosensors, bioelectronics and chemical communication
- Construction of artificial marine environments
- Analysis of gene expression
- Investigation of plant mariculture
- Identification of marine polysaccharides and control of marine pests

INTRODUCTION

In a few short years biotechnology, which was viewed as the science of the future, has rapidly become the technology of the present. What began largely as a descriptive science has led to the development of specific genetic engineering techniques and, as a result, discoveries which will affect the way we live and the way we think. Scientists are now able to capatilize on the efforts of researchers who worked for more than twenty years on projects which gradually revealed the structure and function of the genetic material of organisms. Prominent among capabilities now available to scientists is the ability to move functional genes from one organisms to another. This has generated intensive research efforts in both the basic and the applied sciences.

Efforts to integrate new biological and biochemical technologies into commercial enterprises have been successful in many situations. Still, the phenomenal potential and promise of biotechnology has yet to be fully recognized. Rapid advances in those scientific fields which contribute significantly to advances in biotechnology--e.g., biochemistry, genetics, and microbiology, among others--are stimulating additional basic research in many new areas by posing novel questions to investigators.

As a result of such rapid advances, many people consider scientists engaged in biotechnology-related research to be at the forefront of a new scientific revolution. Scientists mapping the genes of thousands of organisms use the new tools and techniques of modern molecular biology as they chart complex structures that regulate every phase of life. A gene from one organism can now be identified, excised and then inserted into the genome of another organism to impart a desired characteristic, such as the ability to make a useful product--antibiotics, for example.

The implications for agriculture, medicine, aquaculture, and the pharmaceutical and chemical industries will be dramatic. For the chemical industry, biotechnology can mean a considerably reduced dependence on scarce raw materials, as well as an opportuntiy for utilizing new sources of raw materials; for aquaculture, it means the possibility of genetic engineering for high yields of fish and shellfish; for medicine, it means the ability to control disease by administering new vaccines and antimicrobial agents; for agriculture, it means the possibility of improving the hardiness of economically important plants and animals. For example, the improved growth of a plant under drought conditions may be coded by a particular gene. Identifying that gene, isolating it and implanting it into a plant lacking that characteristic can enhance its value for human welfare. Also, many chemicals now manufactured from petroleum products can be made through the water-based chemistry of living organisms. Indigo dye, to cite only one example, is now produced experimentally by inserting several genes from two different organisms into a specially selected bacterium.

Throughout the United States, scientists in universities have been instrumental in research and development which have led to breakthroughs in biotechnology. And, as applications for basic research discoveries have been found, universities have forged new partnerships with industry and government. The common goal of exploring biotechnology requires the pooling of resources and the stimulation of basic and applied research, essential for large-scale development.

The University of Maryland is in the forefront among major universities in developing a network of relationships with government, industry, and other private institutions. Across major research campuses at College Park (UMCP), Baltimore County (UMBC), Baltimore (UMAB), and the Eastern Shore (UMES), the University has diverse expertise and capabilities in biotechnology.

THE ADVENT OF MARINE BIOTECHNOLOGY

Marine biotechnology refers to the manipulation of marine organisms for improving goods and services to benefit humankind. For thousands of years, a kind of biotechnology has been employed in many endeavors: in the selection and breeding of farm animals; in fermentation processes to optimize the quality of bread, wine and beer; in hybridization of crop plants to create desirable traits of growth rates, size, and disease resistance. Today, however, biotechnology has taken on new and exciting dimensions, and the time is ripe for applying this new biological knowledge to the world of marine plants and ani als.

Marine biotechnology's new tools result from breakthroughs in molecular biology and biochemistry, as scientists modify and transplant the genetic information of thousands of different cells and chart the complex molecular structures that regulate every phase of life, from heredity, to growth, to protection against disease. The manipulation of nucleic acids (DNA), hybridoma technology and protoplast fusions can be used to move functional genes from one organism to another and to modify existing biochemical systems to produce useful products. The range of marine-related biotechnolgy endeavors include the development of crops that grow in saline waters and without fertilizer and the engineering of marine microorganisms to attack specific pollutants, such as oil.

Biotechnology in general has already had a sizeable impact on the U.S. economy. In less than ten years, some $2.5 billion has been invested in setting up new companies dedicated to developing products from biotechnology. Monoclonal antibody products have an estimated value of between $20-30 million today with predictions of a $1 billion monoclonal industry by 1990. Genetically manipulated seeds for plants have been projected to increase from $8 million in 1985 to $7 billion by 2000. Amino acids produced either by specific microorganisms or by employing specific enzymes produced by microorganisms have been, and will continue to be, needed in increasing quantities. For example, phenylalanine, one of the two amino acids which make up the sugar substitute, aspartame, has increased in market value from $7.4 million in 1979 to approximately $100 million in 1984. Analysts predict that the world-wide market for phenylalanine will increase to more than $400 million by 1995.

Most biotechnology research has used terrestrial life for its base. Forecasts of economic development and prospects for application to agriculture, medicine, and industry are also based on terrestrial biotechnology. The potential for tapping marine life for equivalent efforts is enormous, though such efforts have been slow and few institutions have demonstrated the necessary combination of marine and other expertise available for its pursuit. It is with the development of marine biotechnology that prospects for new scientific understanding of the vast wealth of ocean life and resultant economic benefits for man will begin to fulfill their exciting promises for the future.

SPECIFIC POTENTIALS OF MARINE BIOTECHNOLOGY

The world's oceans cover approximately seventy percent of the earth's surface. Apart from conventional fish harvesting, only in recent years has attention been directed seriously to the marine environment as a storehouse of a range of resources. As technology has allowed scientists to explore the ocean's depths, new and exciting discoveries have surfaced. The discovery of deep-sea thermal vents and the organisms which inhabit these deep ocean regions generated a great deal of interest within the scientific community. The existence of abundant and active organisms in such thermal regions has demonstrated to scientists that the metabolic potential of organisms is virtually unlimited. For example, recent reports of bacteria living in extremely hot water (more than 250 degrees Celcius)--collected from thermal vents--suggest the possibility for developing a new enzyme-based chemical technology especially applicable to high-temperature industrial uses.

Some of the specific ongoing and potential research areas in the field of marine biotechnology include:

- Drugs from marine sources to block the action of venoms from snakes, scorpions, spiders, and bees.
- Production of new synthetic chemicals modelled on naturally occurring marine toxins for research and commercial applications.
- Industrial chemicals derived from natural marine products that are already used in the food industry, e.g., xanthans, carrageens, gums and agar.
- Specifically engineered marine bacteria to improve treatment of industrial and domestic wastes before discharge.
- Rapid and specific diagnostic tests for fish pathogens using monoclonal antibodies.
- Production of vaccines by recombinant DNA techniques.
- Sensitive biolgoical indicators of those adverse environmental conditions which compromise fish resistance.
- Genetic markers for determining accurate stock assessments of anadromous fish for use by resource management.
- Pharmaceuticals from marine organisms that may be effective against human disease.
- Genetically engineered bacteria to reduce biofouling of ships, pilings, and other structurs in marine environments.
- Microorganisms engineered to dissolve oil sliks and other pollutants.
- Development of strains of shellfish and finfish with desirable characteristics for aquaculture.
- Production of marine polysaccharides as waterproof adhesives.

The potential for research in marine biotechnology and the development of procedures and products based on this research is impressive, and research areas within the field of marine biotechnology remain as varied as the regions of the world's oceans. Marine biotechnology can have an impact on all facets of society--from providing new drugs for the treatment of diseases to increasing food production, to providing a means of removing pollutants from the environment.

The application of genetic engineering to the production of fish, molluscs, and crustaceans in hatcheries and natural environments offers unlimited potential. Not only is it possible to make significant advances in applied genetics of foodstock species through laboratory manipulations of the genetic material of these species, it is also possible to realize major advances in production by developing new methods of diagnosis and control of diseases in environments outside the laboratory, such as fish hatcheries.

Marine pharmaceuticals provide researchers in marine biotechnology with a resource that has yet to be significantly investigated. Numerous compounds have been identified with a spectrum of activity ranging from antibacterial to anticancer to cardiotonic and andrenergic, including a wide variety of compounds from the sea which act on the cardiovascular and central nervous sytems. Marine natural products (and those of any natural source) of high pharmacologic activity are unsurpassed by synthetic compounds. Researchers actively involved in investigating marine natural products with pharmacologic activity report that only a small fraction of such compounds have been identified and described. In addition to providing a direct source of novel drugs for use in experimental and medical applications, marine natural products will serve as models for synthesis or improvement of other drugs.

In this regard, marine toxins are of particular interest to researchers. Toxins--physiologically active and often potent--have the potential to be applied either as drugs or as pharmacological reagents. Even marine toxins which may be too toxic for conventional use can serve as model compounds for studying biochemical mechanisms and for developing new compounds.

Significant promise in marine biotechnology lies in the development of methods for controling the biofouling of ships and other surfaces exposed to ocean water. The presence of biofouling organisms on the hull of a ship, for example, can increase fuel consumption by more than one hundred percent. There is therefore an obvious need for development of methods to control or prevent biofouling. Studies carried out at the University of Maryland have demonstrated that specific marine bacteria may be involved in attracting biofouling invertebrates to surfaces in the marine environment. An understanding of such relationships will aid in the attempt to control the presence and abundance of fouling organisms.

MARYLAND CENTER OF MARINE BIOTECHNOLOGY

Biotechnology brings a new dimension to the marine sciences that offers to expand dramatically the uses of marine and estuarine resources and to provide new tools for the study of complex marine problems. To realize this potential will require an initiative that pools the resources of the research-oriented university with those of industry and government. To date, there have been only a few directed efforts throughout the country, without any concerted program to bring together the wealth of expertise in biotechnology and the marine sciences necessary to pursue aggressively the potential of marine biotechnology.

The University of Maryland has long demonstrated a strong committment to the marine sciences. The Maryland Sea Grant College has developed a comprehensive University and statewide program of marine research, education and advisory services and achieved nationwide recognition for advancing estuarine and marine science for the benefit of those who live and work in the marine environment. Also, Sea Grant's mission and programs for communicating and applying the results of University-based research provide an excellent model and foundation on which to build a solid link with industries and institutions wishing to pursue marine biotechnology applications.

University of Maryland researchers from a number of departments such as botany, chemistry, engineering, medicine, microbiology, and zoology provide a broad base of expertise in marine biotechnology. Researchers are engaged in marine biotechnology and related projects that have already shown promise for application in medicine, aquaculture, and the pharmaceutical industry. For example, the nearby Chesapeke Bay is home to a number of bacteria capable of causing disease in humans and in marine organisms. University scientists are applying the techniques of recombinant DNA to understand the pathogenesis of these diseases, to develop diagnostic techniques for detecting their presence in seafood, and to engineer vaccines that will protect against them.

An important research program at the University is focusing on the processes of molluscan larval attachment to surfaces. Researchers have discovered a bacterium, labeled LST, that serves an important role in the attraction, settlement and metamorphosis of oyster larvae. Prospects for developing a chemical attractant capable of inducing larval setting and metamorphosis promise significant improvement in the productivity of oyster hatcheries, and a patent is pending on this new bacterium. In related projects, research is underway to genetically engineer this versatile bacteria, not only to elucidate the chemical and biological processes of marine biofouling but also to explore the potential for submarine adhesives and other products.

In other fisheries-related research, scientists at the University of Maryland have isolated a virus implicated in mortalities of Atlantic menhaden and striped bass. Monoclonal antibodies to the virus have been generated and are being used to develop sensitive virus-detection methods for use in hatcheries. Research is also focusing on bacteria found in deep sea thermal vents and toxins and other bioactive compounds from marine organisms.

These and numerous other projects construct a solid base from which the University can provide national leadership in marine biotechnology. With the existing expertise in the marine and estuarine sciences, the University has made a significant move forward by adding this innovative program in marine-related biotechnology research.

The essential elements for establishing national and international leadership now exist in the State of Maryland. The State is already attracting biotechnology and high technology industry. Opportunities to attract new industry and to build mutually supportive research and development activities are virtually unlimited. A proven key to attracting biotechnology industries lies in the presence of a university with excellent multidisciplinary expertise, upon which cooperative efforts can be built. The University of Maryland meets such a criterion. In addition, the National Aquarium in Baltimore offers, through its unique resource, experience and facilities for the study of aquatic biology and life-support systems.

Thus, taking advantage of capabilities available within the State, the University of Maryland has built on its strengths in biotechnology and the marine sciences by establishing a unique center of excellence in the promising new area of marine biotechnology. The Univesity of Maryland's Center of Marine Biotechnology will be an invaluable resource for the University, the State of Maryland, the nation--and for the growing pool of scientific knowledge applied to the world's rivers, estuaries, and oceans.

TASK FORCE ON MARINE BIOTECHNOLOGY

Dr. Rita R. Colwell, Chairman
Vice President for Academic Affairs
University of Maryland
Central Administration

Dr. Wayne Bell
Assistant for Special Programs
University of Maryland
Center for Environmental and
Estuarine Studies

Mr. Bernie Berkowitz
Executive Director
Baltimore Economic Development
Corporation

Mr. Nicholas Brown
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NOAA'S OCEAN MINERALS PROGRAM AND THE REAUTHORIZATION OF THE DEEP SEABED HARD MINERAL RESOURCES ACT

THURSDAY, OCTOBER 24, 1985

House of Representatives,
Subcommittee on Oceanography,
Committee on Merchant Marine and Fisheries,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:35 a.m., in room 1334, Longworth House Office Building, Hon. Barbara A. Mikulski (chairwoman of the subcommittee) presiding.

Present: Representatives Mikulski, Tallon, Shumway, Schneider, and McKernan.

OPENING STATEMENT OF HON. BARBARA A. MIKULSKI, A U.S. REPRESENTATIVE FROM MARYLAND

Ms. Mikulski. Good morning, ladies and gentlemen. I'd like to welcome you to today's hearing by the Subcommittee on Oceanography on the reauthorization of the Deep Seabed Hard Mineral Resources Act, on NOAA's Ocean Minerals Program, and on ocean mining generally.

This is both an oversight hearing and a reauthorization hearing. This morning is the second in a series of hearings conducted by this subcommittee concerned with the future uses of the oceans. In July, we considered developments in marine biotechnology. Today we are going to look at the use of the oceans as a source for hard minerals, such as manganese, nickel, and cobalt.

We will hear testimony from witnesses representing Federal agencies, the coastal States, private industry, the environmental community and academia. These witnesses will tell us about the known mineral resources of the ocean and about some of the recent mineral discoveries in the United States Exclusive Economic Zone.

We will hear testimony about the technology that is used in exploration for ocean minerals, and the technology that will be necessary to develop ocean mineral deposits. We will also hear about the economic constraints on ocean mining, and the prospects for developing these valuable resources.

Finally, we will hear recommendations from our witnesses about the role of the Federal and State governments in managing and developing ocean minerals in a manner that protects the marine and coastal environment.

Our first panel will testify about NOAA's Ocean Minerals Program. This program is authorized by the Deep Seabed Hard Mineral Resources Act, which will require reauthorization in 1986.

The Deep Seabed Act was intended to establish a system to manage the development of the manganese nodules found on the floor of the deep seabed, which is defined as the area of the ocean lying outside the limits of the Outer Continental Shelf.

Mr. Paul Wolff, the Assistant Administrator of the National Ocean Service, will discuss NOAA's Ocean Minerals Program. He will also tell us about NOAA's activities in mapping and surveying the U.S. 200-mile Exclusive Economic Zone.

The second panel will examine ocean mining issues generally, and the third panel will focus on the mineral resources of the Exclusive Economic Zone.

Mr. Shumway, do you have an opening statement?

STATEMENT OF HON. NORMAN D. SHUMWAY, A U.S. REPRESENTATIVE FROM CALIFORNIA

Mr. **Shumway**. Yes, I do. Thank you, Madam Chairwoman. I am pleased that you've convened this morning's hearings so that the subcommittee can conduct oversight on our Nation's Ocean Minerals Program. With the present Deep Seabed Hard Mineral Resources Act due to expire next year, this hearing will provide a valuable educational forum as the subcommittee prepares for prospective reauthorization in 1986.

Our Ocean Minerals Program is presently in its early stages—although the manganese nodule resource has been the subject of greater study and as a result is a resource which is likely to be recoverable before some of the other ocean minerals may be.

The potential, however, of these other various ocean minerals, both within our Nation's EEZ and in international waters, although certainly in the speculative phase, is thought to be promising. As a result, I'm particularly interested in the testimony of the industry witnesses and what they believe needs to be done in terms of a regulatory regime to ensure their continued interest in mining ocean minerals in a safe, efficient, and economically viable manner.

I'm also particularly interested in hearing about the minerals research which our Nation has conducted, and how that research has been used by, and coordinated with, the affected industry. Interestingly and ironically, as our geological understanding of how certain ocean minerals are formed increases, so does our predictive capability for discovering similar minerals on land. The end result of this ocean geological research might well be a postponement of the need for ocean mineral recovery if, as a result of the research, more economical land minerals become available.

We have this morning a balanced panel of witnesses, and I am pleased to welcome them to our subcommittee.

Ms. **Mikulski**. Thank you, Mr. Shumway. Before we proceed with the first panel, however, our colleague, Mr. Bosco, wishes to testify on his bill which also has an impact on mineral leasing. His bill is H.R. 2048, to prohibit the leasing of mineral areas in the Gorda

Ridge Outer Continental Shelf offshore his northern California district.

The bill requires a study by Interior and Commerce on the environmental effects of mineral exploitation in this area and action by Congress before leasing can begin. And since this does deal with the issues of ocean mining and taking a look at what might be a new legislative framework related to minerals development, we would welcome the commentary of Mr. Bosco on his particular bill at this time.

Mr. Bosco?

Mr. Bosco. Thank you, Madam Chairwoman.

STATEMENT OF HON. DOUGLAS H. BOSCO, A U.S. REPRESENTATIVE FROM CALIFORNIA

Mr. Bosco. I appreciate this opportunity to appear before the subcommittee today and speak on an issue that is of great importance to the people of my northern California district and the people of our State. As one who represents nearly one-third of the California coast, I can attest to the contentious nature of any governmental activities involving the Outer Continental Shelf.

The members of this subcommittee are well aware, I'm sure, that one of the most controversial issues facing California today is the Offshore Oil Leasing Program. Some day I hope that we will be able to resolve those issues and get that problem behind us. But I think when that does happen, we will find that the mineral leasing plans for the Government may well replace the offshore oil in terms of the level of controversy that it engenders.

For this reason, I think it is important that this program get off to the right start, that we know enough about it to begin with to quell any doubts that the public might have, and that hopefully the Interior Department would do a much better job of the offshore mining operations than they have with the offshore oil ones.

At least in the initial stages the Interior Department's handling of the Offshore Mining Program does not leave us much room for optimism. Interior first announced plans for the Gorda Ridge lease sale in March 1983, only a few weeks after President Reagan announced the creation of the Exclusive Economic Zone which gave the United States jurisdiction seaward to the Outer Continental Shelf.

The Department proposed to lease more than 70,000 square miles of seafloor. Then, less than 9 months later, the minerals management service issued a draft environmental impact statement and scheduled the lease sale for August 1984. Unfortunately, the draft EIS made it abundantly clear that no one, least of all the minerals management service, had any idea how the mining would be done, what the environmental impacts would be, or if the Gorda Ridge even had any mineral potentials. Faced with broad public and private industry criticism, the draft EIS was withdrawn.

The manner in which the Department mishandled both the early stages of this program as well as the Offshore Oil Program and Gas Leasing Program leads me to believe that strong congressional guidance over the direction taken by the Department is absolutely necessary.

More to the point, our ocean mining policy should be guided by the belief that responsible stewardship of our publicly owned mineral resources requires a solid base of sound information. One of the problems that we've had consistently with the Offshore Oil Program, including the recent breakup of the agreement that the California delegation had with the Interior Department—one which I felt was fair to both sides—but one of the problems that we've had is that there is a lack of information about these resources in general.

I don't believe that the Interior Department should be in the business of auctioning off the public resources at possible fire sale prices until more definitive scientific, environmental, and economical information is gathered and analyzed.

Here I might say that I cannot imagine any sound business practice which would allow them to, in a matter of months, lease 70,000 square miles off the coast of California when they have no idea of the mineral content, they have no idea of what use these minerals would be put to, who would bid on them, or what value the entire public estate in that case is.

The legislation that I have introduced, H.R. 2048, embraces these beliefs by slowing down the Gorda Ridge Program while we develop a strong information base upon which to make intelligent policy decisions. H.R. 2048 would prohibit lease sales on the Gorda Ridge until at least 1989, while directing the President to submit a feasibility study to Congress no later than September 30, 1989.

In closing, there is no economic or national security rationale for rushing ahead with deep sea mining. And I think we could all save ourselves a lot of trouble by trying to resolve some of the unanswered questions before we embark on these lease sales. Without passing judgment on the ultimate wisdom of mining offshore, which I think, as Mr. Shumway said, may very well be a profitable and valuable endeavor for our country, I would hope that we at least take a careful, thorough, and pragmatic approach to this issue, more so than we have with the offshore oil. Without such an approach, I can assure you that we will only see much of the same litigation and moratoriums that have already clouded our offshore oil and gas programs.

I applaud the subcommittee for giving this important matter the careful attention it deserves. And thank you Madam Chairwoman and Mr. Shumway for your attention this morning.

Ms. Mikulski. Thank you very much Mr. Bosco, and we look forward to further conversation with you on your bill once we have this overall framework on deep seabed mining. Thank you very much.

Mr. Bosco. Thank you.

[Mr. Bosco's bill follows:]

99TH CONGRESS
1ST SESSION

H. R. 2048

To prohibit temporarily certain hard mineral leasing in the Gorda Ridge Outer Continental Shelf area, to require a report on the effects of such potential leasing, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

APRIL 16, 1985

Mr. BOSCO introduced the following bill; which was referred jointly to the Committees on Interior and Insular Affairs and Merchant Marine and Fisheries

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A BILL

To prohibit temporarily certain hard mineral leasing in the Gorda Ridge Outer Continental Shelf area, to require a report on the effects of such potential leasing, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Ocean Mineral Resources Development Act".

SEC. 2. No Federal agency shall offer for lease under the Deep Seabed Hard Mineral Resources Act, the Outer Continental Shelf Lands Act, or any other Federal law, any of the area off the Pacific coast known as the Gorda Ridge, bounded by latitude 40 degrees to 45 degrees north and longitude 125 degrees to 129 degrees west but not including any areas seaward of the 200 nautical mile Exclusive Economic Zone of the United States, for exploration, development, or production of polymetallic sulfide or other hard rock minerals, until such time as the President has submitted a Gorda Ridge feasibility report to the Congress under section 4 of this Act and the Congress has lifted such prohibition on leasing by joint resolution, or until after September 30, 1989, whichever occurs earlier.

SEC. 3. The Secretary of Commerce and the Secretary of the Interior shall, after consultation with any other agencies of the United States having responsibilities under law for research and other scientific studies relating to the Gorda Ridge area described in section 2 of this Act, and taking into account the concerns of any State agencies, including federally approved Coastal Zone Management Programs, prepare and submit to the Congress, no later than one year after the date of enactment of this Act, a memorandum of understanding clarifying the respective responsibilities of each department or agency of the United States with respect to such research and other scientific studies under law and with respect to studies required to be made under section 4 of this Act.

SEC. 4. The President shall prepare and submit to the Congress, no later than September 30, 1988, a Gorda Ridge feasibility report which shall include—

(1) a summary of knowledge of the physical, chemical, and biological environment of the Gorda Ridge, including the location, characteristics, and extent of hydrothermal vent communities;

(2) a study of oceanic processes in the Gorda Ridge area, including the chemistry, circulation patterns, and current velocities, especially in near-bottom waters;

(3) a study of the potential impacts of mining, processing, and disposal on the Gorda Ridge area's biota, including biological responses to potential environmental modifications;

(4) a study of the adequacy of heavy metal standards for potentially affected deep ocean, coastal, and estuarine waters and wetlands, including shoreside facilities, and the potential impacts of mining, processing, and disposal on water and air quality in those areas;

(5) a determination of what, if any, additional technology and exploratory activity is necessary to fill the scientific data gaps concerning the Gorda Ridge;

(6) a study of the feasibility of mining in the Gorda Ridge area, including recommendations as to

the most feasible methods of exploratory and production activities;

(7) a study of the current state of potentially affected metals markets, including a projection of the availability of metals from all sources to satisfy market demand; and

(8) recommendations as to the most appropriate leasing procedures and lease values for exploratory and production activities on the Gorda Ridge.

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October 17, 1985

MEMORANDUM

TO: Members, Subcommittee on Oceanography

FROM: Subcommittee Staff

RE: October 24, 1985, hearing on ocean mining and oversight of NOAA's Ocean Minerals Program, including reauthorization of the Deep Seabed Hard Mineral Resources Act

On October 24, 1985, the Subcommittee on Oceanography will hold a hearing to receive testimony regarding ocean mining and NOAA's Ocean Minerals Program, including testimony on reauthorization of the Deep Seabed Hard Mineral Resources Act (Public Law 96-283).

Testimony is scheduled to be presented by Paul Wolff, Assistant Administrator of NOAA for the National Ocean Service; Dallas Peck, Director of the U.S. Geological Survey (Department of the Interior); James Broadus, of the Woods Hole Oceanographic Institution; Conrad Welling, with the Ocean Minerals Company; Richard Greenwald, with Ocean Mining Associates; Myron Nordquist, of Kelley, Drye, & Warren; Clifton Curtis, of the Oceanic Society; and Robert Knecht, of the University of California at Santa Barbara.

1. ACTIVITIES UNDER DEEP SEABED HARD MINERAL RESOURCES ACT (DSHMRA)

The DSHMRA was enacted in 1980, in response to industry and international interest in developing the technology for, and beginning commercial recovery of, manganese nodules from the floor of the deep seabed. (The "deep seabed" is the area seaward of any submerged lands claimed by coastal nations under "continental shelf" or "exclusive economic zone" legal theories. The manganese nodule mineral resource is explained in some detail later in this memo.) Enactment of the DSHMRA occurred while negotiations at the Third United Nations Conference on the Law of the Sea (UNCLOS III) were still continuing.

The DSHMRA was the product of about nine years of Congressional consideration. Basically, the DSHMRA responds to uncertainties about the legal status of deep seabed miners in international waters. According to NOAA, U.S. companies and their international corporate partners trying to explore and develop the manganese nodules found themselves in a dilemma: they could not continue indefinitely to risk their own investment nor, because of the lack of assured exclusive access to a deep seabed mine site, could they obtain from financial institutions the enormous capital (which probably would exceed $1 billion for each mining venture) to exploit those resources commercially. The international consortia, cumulatively, have invested a total of about $400 million in exploring, and planning commercial operations, for manganese nodules.

The DSHMRA establishes what was called an "interim" program to regulate exploration for commercial recovery of deep seabed manganese nodules by U.S. citizens. In particular, the Act provides a mechanism whereby citizens who meet certain requirements in the law may obtain priority of right and assured access to engage in deep seabed mining exploration and, eventually (beginning in January, 1988), commercial recovery within high seas areas selected by the companies.

The Act is intended: (a) to provide sufficient regulatory certainty to enable continued development of the deep seabed manganese nodule mining industry, and (b) to provide an orderly progression from a situation of no regulation of deep seabed mining activities to, first, U.S. regulation of its citizens who conduct deep seabed mining activity with mutual recognition of miners operating under comparable legal regimes enacted by other countries and, ultimately intended in the original DSHMRA, mining under the international regime established in the LOS negotiations if and when an LOS treaty enters into force for the United States.

In principal features, the Act:

(a) authorizes NOAA to issue, to U.S. citizens, licenses for exploration of manganese nodules in the deep seabed after July 1, 1981, and permits which authorize commercial recovery to begin no earlier than 1988. Licenses and permits are subject to regulations imposed by the Administrator of NOAA and appropriate terms, conditions, and restrictions. Commercial recovery vessels must be documented in the United States and, except in limited circumstances, recovered minerals must be processed at plants located in the United States;

(b) requires promulgation of regulations addressing such issues as protection of the marine environment, conservation of natural resources, and safety of life and property at sea. NOAA has issued regulations pertaining to issuance of exploration licenses and the conduct of exploration activities. While preparing these regulations, NOAA also prepared a programmatic Environmental Impact Statement (EIS) on the regulations. A site-specific EIS must be prepared for each license or permit. The Act prohibits issuance of a license or permit if the activity can reasonably be expected to have a significant adverse effect on the quality of the environment that cannot be avoided or appropriately mitigated, or poses an inordinate threat to life and property at sea;

(c) authorizes the Administrator, in appropriate cases, to amend regulations, terms, conditions, and restrictions in licenses and permits as experience with deep seabed mining is gained, and contains provisions regarding monitoring, enforcement, and the suspension, revocation, or modification of a license or permit;

(d) directs the Administrator to conduct an accelerated program of ocean research to support environmental assessment activities necessary to determine whether ocean mining activities will have a significant adverse effect on the marine environment;

(e) encourages conclusion of a comprehensive LOS treaty which assures nondiscriminatory access to deep seabed hard mineral resources; the Act also establishes a revenue sharing fund for the purpose of making such payments as may be required by the revenue sharing provisions of an LOS treaty, if and when such a treaty enters into force with respect to the U.S.; and

(f) empowers the Administrator to designate foreign nations as "reciprocating states" for the purpose of providing mutual recognition of mining rights if the laws of those nations regulate deep seabed mining in a manner compatible with DSHMRA and its implementing regulations.

On September 15, 1981, NOAA issued final regulations governing exploration licenses and activities. NOAA has drafted proposed regulations addressing commercial recovery permits and activities, but these regulations have not been published in the Federal Register because the Office of Management and Budget (OMB) raised numerous specific questions about the purpose, authority, and various provisions of those regulations. OMB has held up publication of those proposed regulations for approximately one and one-half years. NOAA also has experienced lengthy delays in obtaining Commerce Department-level approval of these proposed regulations.

The DSHMRA has been reauthorized twice since the original enactment, but has not been substantively amended. The most recent reauthorization was part of Public Law 98-623 (November 8, 1984) and authorizes $1.5 million for each of Fiscal Years 1985 and 1986.

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APPLICATIONS FOR EXPLORATION LICENSES

In early 1982, NOAA received applications from the four "U.S." industrial consortia: Ocean Minerals Company (OMCO), Ocean Management, Inc. (OMI), Ocean Mining Associates (OMA), and the Kennecott Corporation consortium. Each of these consortia is comprised of several international companies, including Mitsubishi, U.S. Steel, Union Miniere, Sedco, INCO (International Nickel), Lockheed, Amoco, and Royal Dutch Shell (or subsidiaries), among others. (See Figure 1 for additional information on the identity and nationality of companies comprising these four consortia.) During the summer and fall of 1984, NOAA issued exploration licenses to each of these four consortia. (No permits for commercial recovery have been issued.)

THE RECIPROCATING STATES AGREEMENT

In August, 1984, the United States and seven other countries with significant interest in, and ability to undertake, seabed mining signed an agreement entitled "Provisional Understanding Regarding Deep Seabed Matters", known informally as the Reciprocating States Agreement (RSA). Signing with the United States were Belgium, France, the Federal Republic of Germany, Italy, Japan, the Netherlands, and the United Kingdom. The agreement pertains to the four so-called U.S. consortia, to French and Japanese Government-sponsored consortia, and to any new entrants to the industry if based in RSA nations.

The Agreement is aimed at:

(1) avoiding conflicts over deep seabed mine sites, assuring that the nations party to the Agreement will recognize the rights of a licensee in another country (thereby enhancing "tenure" of a licensee to a particular site and facilitating financing of seabed mining operations);

(2) establishing minimum requirements for matters such as diligence, enforcement, conservation of the resource, environmental protection, and safety of life and property at sea (this assures a basic minimum regulatory framework, thereby avoiding creation of "flag of convenience" seabed mining countries which might have minimal regulation); and

(3) providing for regular consultation among the parties with respect to deep seabed mining.

RELATION OF RSA TO LOS TREATY

The RSA negotiations began in 1980, when the U.S. still had some hopes of concluding a Law of the Sea Treaty that would provide an acceptable, nondiscriminatory international legal and management regime for deep seabed mining. The RSA was portrayed as an interim regime to allow the industry to proceed, pending entry into force for the U.S. of the LOS Treaty.

President Reagan decided the U.S. would not sign the LOS Treaty, principally because its seabed mining provisions are unacceptable. Some members of the RSA group have signed the LOS Treaty (e.g., France and Japan), and other RSA members joined the U.S. in refusing to sign (e.g., the U.K. and FRG). Not one of the RSA countries has ratified the LOS Treaty. Entry into force of the LOS Treaty is problematical -- 60 ratifications are required. The RSA can provide a long-term legal/management framework if the LOS Treaty never enters into force.

THE MANGANESE NODULE RESOURCE

The DSHMRA applies only to one type of mineral resource: manganese nodules. Manganese nodules are fist-sized concretions of manganese, iron, and other minerals that occur on the sea bottom in areas of low sediment deposition around the world. Manganese nodules are particularly rich in four metals -- nickel, cobalt, manganese, and copper. Nickel, currently supplied to the United States chiefly from land-based mines in Canada and New Caledonia (in the South Pacific), is used mainly in stainless steel and other high temperature steel alloys. Cobalt, which the United States currently obtains primarily from Zaire, is used in the electrical industry for permanent magnets, and for high temperature alloys used in aircraft. Manganese, which is supplied to the United States by Brazil, Gabon, South Africa, and Australia, is essential to the production of steel. The only other large onshore reserve of manganese is in the Soviet Union. Copper, in which the United States is nearly self-sufficient, is used mainly in electrical equipment. The United States is particularly dependent upon foreign sources for cobalt and manganese, currently importing about 95 percent of our cobalt and 99 percent of our manganese.

If commercially feasible, nodule mining can provide what may be an increasingly important additional source for these strategic metals if current foreign sources become unavailable to us.

While nodules have been found in all of the world's oceans and in some large lakes (e.g., Lake Michigan), commercial interest is centered in the equatorial North Pacific Ocean, approximately halfway between Hawaii and Mexico. The nodules in this area have metal content that is of greater commercial interest. The water depth in the area ranges from 12,000 to 18,000 feet. (See Figures 2 and 3.)

TECHNOLOGY FOR COMMERCIAL MINING OPERATIONS

The international consortia have been working on three main types of mining systems: hydraulic, continuous line bucket, and independent "shuttle". (See Figure 4.)

Hydraulic systems, using either submerged pumps or airlift systems, are favored by the so-called U.S. consortia. Hydraulic mining systems use a seabed collector, which gathers up the nodules, together with some sediment and some biota. As much extraneous material as possible is ejected near the seafloor. The nodules and remaining material are pumped in a seawater slurry through a pipeline up to a mining ship on the surface. The hydraulic collector may be either towed or self-propelled. The Ocean Minerals Company's Archimedes screw design is the only self-propelled hydraulic system. It is fair to say that the hydraulic collector mechanisms anticipated, for full-scale commercial operations, would be as big as a house.

A Japanese group has studied continuous line bucket systems. The French are developing a "shuttle" system using free-swimming, remotely-controlled mining vehicles.

The onshore aspect of deep seabed mining involves at least three major activities: the use of port facilities, a facility for processing the nodules, and a site for disposal of processing tailings and other wastes. Onshore processing basically will use well-established refining technology and methods currently used to process land-derived ores.

II. NON-NODULE MINERAL RESOURCES OF THE EXCLUSIVE ECONOMIC ZONE

On March 10, 1983, President Reagan proclaimed a "200-mile" Exclusive Economic Zone (EEZ) for the United States, applicable to the seabed area off the various states, and off of the island territories and possessions of the United States (see Figure 5). The total seabed area encompassed in the EEZ Proclamation is about 3.9 billion acres (compared to the total onshore area of the United States and its territories of only 2.3 billion acres). A major issue for this hearing concerns what management regime should apply for exploration and development of hard mineral resources in the EEZ.

POLYMETALLIC SULFIDES

Among the recently discovered mineral resources of the EEZ are polymetallic sulfides (PMS), which are found in rift zones or spreading centers, for example, the Gorda Ridge located approximately 60 miles off Northern California and Oregon and the Juan de Fuca Ridge located further seaward off Oregon, Washington, and Canada.

In a rift zone, there are faults in the earth's crust by which molten rock can rise and reach the seafloor. As seafloor spreading continues, these faults also provide conduits for cold seawater to circulate downward into the hot crust. The water reacts with the hot rock, leaching from it elements such as manganese, zinc, iron, copper, molybdenum, silver, and cadmium. The hot rock heats the water, and the hot (up to 400° C) mineral-laden water is driven upward toward the seafloor where it encounters the cold deep ocean water, and some of the minerals dissolved in the water precipitate onto the walls of the fault and onto the seafloor. The hot mineral-laden water shoots upward much like an underwater geyser; such plumes, first discovered in 1978, are called "smokers", because most of the plumes are black with rich mineral content.

Totally new and unexpected varieties of marine life have been found associated with these hot thermal vents. Biologists have discovered that these communities are chemosynthetic, that is, their life cycle is basically dependent upon species of bacteria which can oxidize and draw energy from sulfides which are contained in the vent waters. These new organisms include not only bacteria, but also new varieties of clams, huge five-foot-long tube worms, and crabs. These are the only known communities on the earth that do not depend upon the sun and photosynthesis for their basic source of energy. Scientists also are amazed that these animals can survive the high temperatures and toxic hydrogen sulfide associated with the vents.

Scientists do not know how many of these sulfide vents, and associated precipitated mineral deposits and unusual life forms, may exist along the approximately 40,000 miles of the worldwide network of ocean spreading centers or ridge crest systems (see Figure 6).

COBALT-RICH MANGANESE CRUSTS

The EEZ also includes waters adjacent to Puerto Rico, the Virgin Islands, the Hawaiian Islands, the Northern Mariana Islands, and other islands in the Pacific Ocean, such as American Samoa and Johnston Island. Surrounding a number of these islands and nearby seamounts (which are, essentially, submarine volcanoes which do not break the surface of the water) are crustal deposits which consist principally of manganese, but which have been found to have a very high cobalt content, and some platinum and chrome. These manganese crust deposits occur in thicknesses up to approximately four inches, and may extend over tens or hundreds of square kilometers in a particular area. These cobalt rich manganese crusts may be of great interest to the United States in our search for additional secure supplies of strategic or economically critical minerals, because many of these crusts are found in the United States Exclusive Economic Zone, not just in a foreign country or in international waters.

A West German company, Preussag, is currently exploring for cobalt crusts near Hawaii and Johnston Island. Nippon Kokon K.K. (the second largest Japanese steel company) and Brown & Root also are affiliated with this exploration.

SAND, GRAVEL, PHOSPHORITE, AND PLACERS

Perhaps less exotic, but still of commercial interest, are EEZ deposits of sand, gravel, and phosphorite (a principal component of agricultural fertilizer).

Placer deposits consist of sediments washed off the continent in rivers, etc. They include potentially economic amounts of minerals such as gold, platinum, and titanium.

FEDERAL AGENCY EEZ RESEARCH; TECHNOLOGY AND NATIONAL SECURITY CLASSIFICATION ISSUE

Several Federal agencies are, or are expected to be, involved in mapping the EEZ, locating offshore minerals, and conducting related oceanographic and environmental research. The agencies primarily involved are: NOAA, the U.S. Geological Survey (USGS), and the Minerals Management Service (MMS).

The respective responsibilities of NOAA and the USGS in conducting a joint program of EEZ bathymetric surveys and data analysis are set forth in a Memorandum of Understanding (MOU) signed in April, 1984. NOAA's primary responsibilities include surveying, mapping, oceanographic analysis, and the storage of data. USGS's primary responsibilities include defining the seafloor geology and geological processes, and characterizing and quantifying energy and mineral resources of the EEZ.

Other agencies with a role in EEZ research include the National Science Foundation (NSF) and the Bureau of Mines in the Department of the Interior.

For a detailed discussion of each agency's EEZ research programs and budgets, please see the Attachment to this memo.

Exploration for polymetallic sulfides and manganese nodule crusts has been greatly facilitated by recent technological developments. The submersible ALVIN has been used on numerous dives to thermal vent areas in the Galapagos Ridge area and in the Gorda and Juan de Fuca Ridge areas off the U.S. West Coast. The new robot vehicle ARGO, used by Dr. Robert Ballard in the successful search for the TITANIC, is scheduled for use on Ballard's next project -- exploration of the submarine mountains and hot vents of the East Pacific Rise (off Mexico), according to the September 27, 1985, edition of Science magazine.

New bathymetric survey technologies, such as the SEABEAM and GLORIA systems, have given scientists a tremendously enhanced view of seabed bathymetry. Indeed, the information obtained by these devices, which are basically multiple towed-array sonar systems with a computer to process the multiple data images, has been so good that the U.S. Navy has directed NOAA to classify all of its bathymetric data obtained on recent cruises to map the seabed of the EEZ. The Navy is highly concerned that public release of the detailed bathymetry (accurate to within 10 meters of vertical elevation), when combined with modern precision navigation systems, and with other information such as geophysical data, could provide an enemy submarine with a new means of fixing its position with great precision for the purpose of calibrating ballistic missiles.

To oversimplify the issue somewhat, there is no legal means by which we could prevent the Soviet Union from coming into most of our EEZ with its own equipment and obtaining this information for itself, but the Navy would prefer not to have NOAA make this information publicly available on a comprehensive basis. The Navy would rather make the Russians at least pay out of their own pockets for acquiring this information.

However, restrictions on access by academic and industry researchers to U.S. bathymetric data would slow exploration and development of EEZ resources. Staff have been told by NOAA that a National Security Council subcommittee has proposed a methodology for degrading some information for public release, and a procedure to allow security-cleared academic and industry researchers access to the more accurate, classified data. NOAA says they "can live with" the proposed security arrangements, but it is not clear whether the Navy will agree.

III. JURISDICTION/MANAGEMENT ISSUES

The Department of the Interior Solicitor's Office issued a legal opinion on May 30, 1985, which asserts that the Outer Continental Shelf Lands Act is the legal regulatory statute governing the exploration and development of all mineral resources within the U.S. EEZ (at least out to 200 nautical miles from shore off of each state of the United States). This legal position has been strongly questioned, both by Members and staff of the Merchant Marine and Fisheries Committee, and by several attorneys representing potential miners.

A strong legal case can be made that the Outer Continental Shelf Lands Act was never intended to apply seaward of the continental shelf, or at least not seaward of the geological continental margin (shelf, slope, and rise). Many of the areas of the EEZ which are of new interest for mineral potential are located seaward of the continental margin. Critics of the Solicitor's opinion also note that President Reagan's EEZ Proclamation was not intended to automatically extend the jurisdiction of the OCS Lands Act in any way. The net result of the President's Proclamation, under this analysis, was to claim EEZ resources beyond the continental margin for the United States vis-a-vis foreign nations, but to leave a "gray area" with respect to the question of what domestic management regime would apply to any newly claimed seabed areas seaward of the continental margin yet inside 200 miles.

An additional management regime uncertainty is that the OCS Lands Act applies only seaward of the states of the United States. That is, the OCS Lands Act does not apply in areas such as the Northern Mariana Islands, American Samoa, or Johnston Island. Since some of these areas may be of prime interest to mineral explorers, it is clear that some legislative action will be required to establish a legal regime for EEZ mineral development.

The Department of the Interior has established a special ocean mining office, the Office of Strategic and International Minerals, as part of the Minerals Management Service. DOI is drafting exploration regulations, pursuant to the OCS Lands Act, and plans to issue the exploration regulations within the next couple of months. Separate packages of regulations pertaining to leasing, and to commercial operations, would follow, with hopes of having all three stages of regulations in effect sometime in 1988.

However, several industry representatives have expressed great concern that any regulations which the Interior Department might issue pursuant to the OCS Lands Act would be so heavily influenced by the oil and gas regulatory experience that development of the hard mineral mining industry would be severely impeded.

IV. COMMERCIAL/BUSINESS CONSIDERATIONS

Development of the various seabed mineral resources may occur either for purely commercial reasons or for reasons motivated more by national security or national critical economic concerns.

Industry witnesses are expected to testify that, if only business considerations are taken into account, there probably will be no commercial-scale mining of these ocean minerals until sometime in the next century. At present, some world metals market prices are below actual production costs. This means that commercial development of seabed minerals awaits the occurrence of one or more of the following four events:

(1) price increases,

(2) a technology breakthrough,

(3) discovery of a bonanza-sized deposit, or

(4) establishment of a financial subsidy to mining companies, for political or national security-type reasons.

The mining industry sees different development potential in the different types of seabed mineral resources. Regarding manganese nodules, the nodules in the Eastern Tropical Pacific (the Clarion-Clipperton Zone) are of better quality than nodules on the Blake Plateau off of northern Florida and Georgia, with respect to manganese, copper, and nickel content. The cobalt content of nodules from these two different locations is approximately the same.

Regarding the cobalt-rich manganese crusts, some pavement-type deposits seem mineable, but the mining technology to scrape or cut the crust (they can be up to about four inches thick) and lift the crust to a surface mining vessel has not been developed.

Cobalt and platinum concentrations are higher in crusts than in manganese nodules, but nickel, copper, and zinc concentrations are lower in the crusts than in the nodules.

Polymetallic sulfide deposits found to date have varied significantly in their metal content from site-to-site. Major minerals in the PMS deposits include copper, lead, silver, and zinc. Industry members have said that precious metals may be the governing factor in development of PMS deposits.

Accordingly, the rate of development of these various resources may well depend upon whether the United States wishes to let commercial world market economic forces operate, or whether the U.S. wishes to encourage mining of particular deposits, perhaps for national security reasons.

Industry also feels strongly that the OCS Lands Act regulatory regime is likely to stifle development of the marine mining industry. For example, the mining industry objects to the OCS Lands Act practice of requiring high front-end cash bonus bids at the time of a lease sale. Also, industry would like to see some sort of preferential priority of right given to miners who invest in exploration. DOI says they are willing to consider these ideas, but industry is skeptical. Perhaps a statute specially designed for ocean mining might adapt the mineral patent rights system which has been employed for staking claims on land, and adapt requirements pertaining to maximum patentable area and diligence.

V. ENVIRONMENTAL EFFECTS

The environmental effects of ocean mining activities will occur at or near the seafloor, in the water column, at the surface, and because of processing activities, at sea or on land. Most environmental studies that have been conducted to date concern the effects of ocean mining for manganese nodules (see Figure 7), and NOAA has prepared a five-year environmental research plan as required by the DSHMRA. The environmental impacts resulting from mining crusts and polymetallic sulfide deposits have not been studied as extensively.

Nodules will most likely be recovered from the seabed by a collector that will be pulled or driven on the seafloor. As a result, benthic (bottom-dwelling) biota will be destroyed through physical contact with the collector and by the sediment plume that will be created by the collector churning up the sediment. Recolonization rates for disturbed areas are unknown, and may involve long periods of time.

Transporting nodules to the surface will also bring up deep ocean water and sediments, which will be discharged back into the ocean, creating a sediment plume that may take a very long time to settle. The environmental effects of this plume are not fully known, but it is expected to be detrimental to phytoplankton, and to impair photosynthesis by reducing light penetration. This discharge from the mining ship will require a Clean Water Act NPDES permit from EPA (see Section 109(e) of DSHMRA).

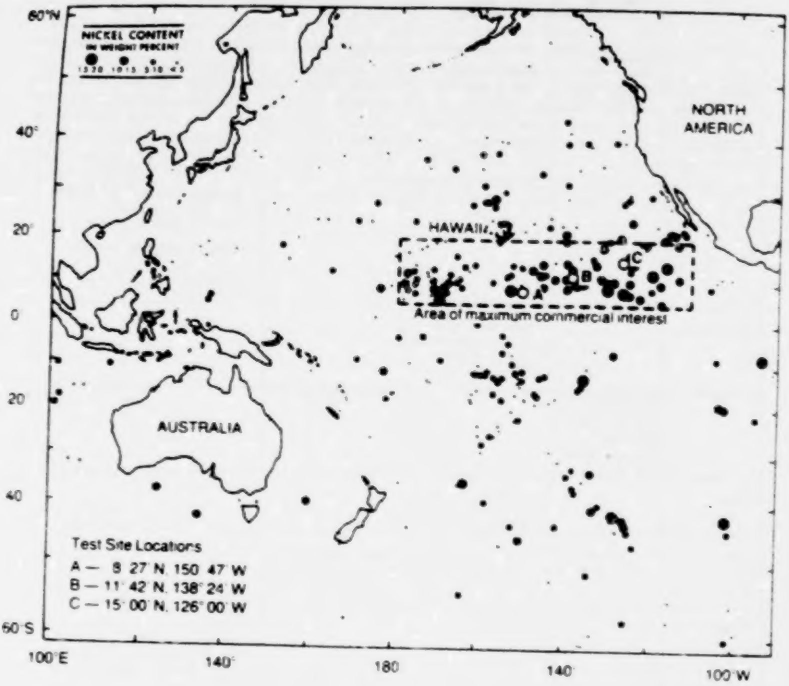
Processing minerals at sea (not viewed as a likely option at present) may have harmful environmental effects because of the at-sea disposal of large amounts of "waste" containing metal tailings, trace elements, and toxic reagents used in the processing. Processing onshore in coastal areas may cause significant pollution locally, and will require a means to dispose of large amounts of wastes. Depending upon whether three metals (copper, nickel, and cobalt) or four metals (manganese) are recovered from nodules, waste accumulations may amount to either 97 percent or 70 percent of the total minerals processed. The onshore processing facilities, and the types and volumes of processing wastes, are quite similar to facilities and wastes involved when processing ores mined from land-based sites.

Figure 1

Deep seabed mining consortia involving United States firms and parent companies, including dates of consortia formation, as set forth in applications filed with NOAA in February 1982.

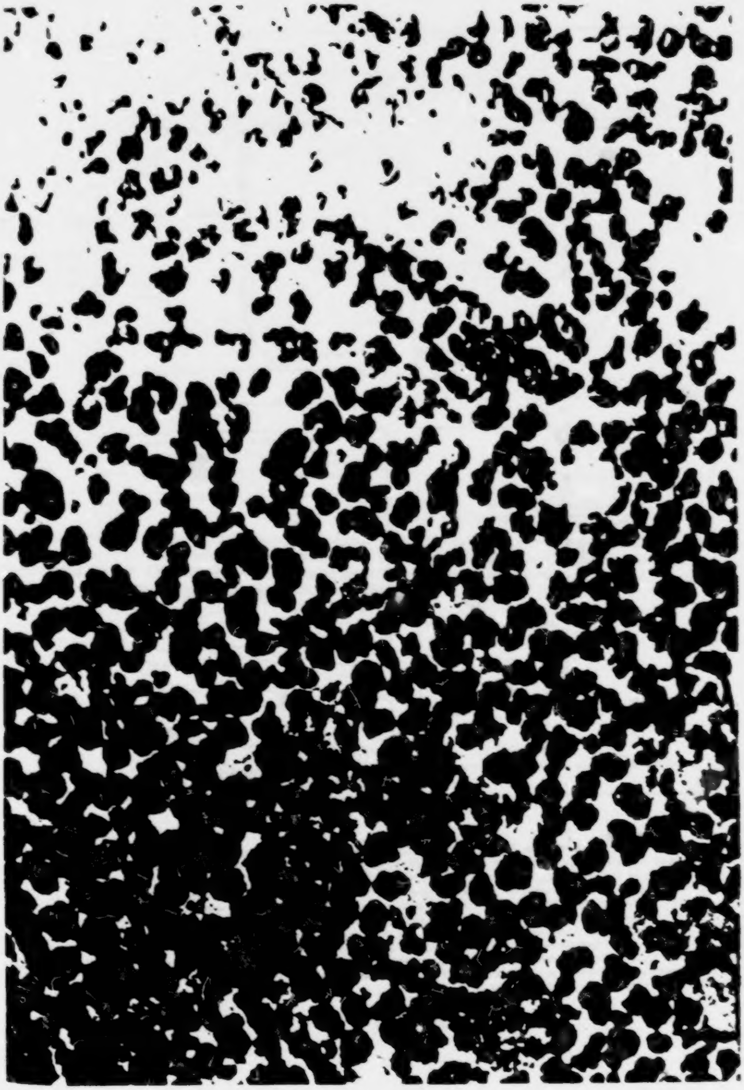
Nation	Kennecott Consortium (KCON) (1/74)	Ocean Mining Associates (OMA) (10/74)	Ocean Management Inc. (OMI) (5/75)	Ocean Minerals Company (OMCO) (11/77)
United States		Essex Minerals Co. (U.S. Steel) 25% Sun Ocean Ventures Inc. (Sun Co.) 25%	Sedco, Inc. 25%	AMOCO Ocean Minerals Co., (Standard Oil Co. (Indiana)) 30.669% of OMCO Lockheed Systems, Co., Inc. (Lockheed Corp.) 6.329% of OMCO Lockheed Missiles & Space Co., Inc., (Lockheed Corp.) 38.64% of OMInc.
Belgium		Union Seas, Inc. a U.S. corporation (Union Miniere) 25%		
Canada	Noranda Exploration, Inc., a U.S. corporation 12% (Noranda Mines Ltd.)		INCO, Ltd. 25%	
Italy		Samim Ocean Inc., U.S. corporation (ENI/Italy) 25%		
Japan	Mitsubishi Corp. 12%		Deep Ocean Mining Co., Ltd. (DOMCO-19 Japanese Companies) 25%	
Netherlands				Ocean Minerals, Inc. (OMInc., a U.S. corp.) 63.002% of OMCO -Billiton B.V. 48.68% of OMInc. (Royal Dutch/Shell Group) -BKW Ocean Minerals 12.68% of OMInc., (Royal Boskalis Westminster N.V.)
United Kingdom	Kennecott Corp., a U.S. corporation (Sohio/BP) 40% R.T.Z. Deep Sea Mining Enterprises, Ltd. (Rio Tinto-Zinc) 12% Consolidated Gold Fields, PLC 12% BP Petroleum Dev., Ltd. 12% (The British Petroleum Co., p.l.c.)			
West Germany			AMR 25% (Preussag A.G., Salzgitter A.G., Metallgesellschaft A.G.)	

Figure 2


NICKEL CONTENT
IN WEIGHT PERCENT
1.5 2.0
1.0 1.5
.5 1.0
< .5
NORTH AMERICA
HAWAII
Area of maximum commercial interest
A
B
C
AUSTRALIA
Test Site Locations
A — 8° 27' N. 150° 47' W
B — 11° 42' N. 138° 24' W
C — 15° 00' N. 126° 00' W
60°N
40°
20°
0
20
40
60°S
100°E
140°
180
140°
100°W

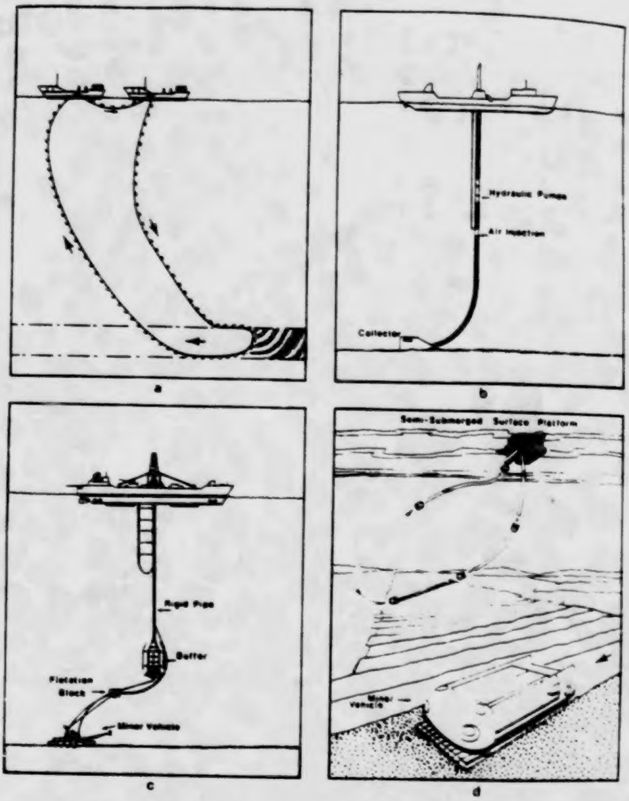
Area of manganese nodule maximum commercial interest and high nickel concentration in nodules with DOMES test site locations (Horn, Horn, and DeLach, 1972).

Figure 3



Manganese nodules on seafloor.

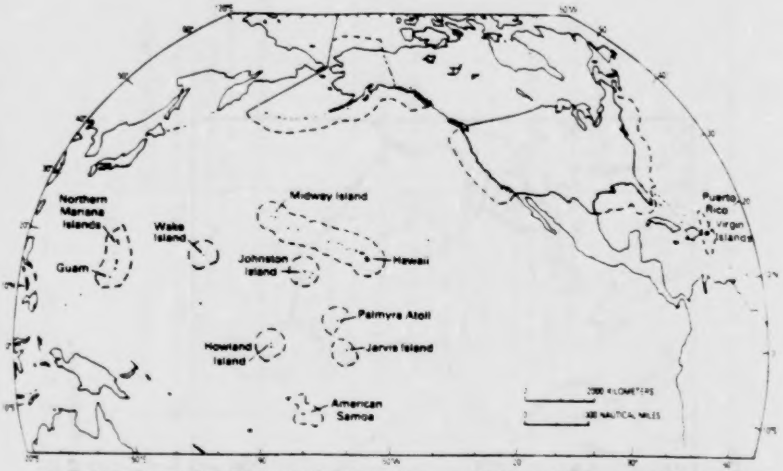
Figure 4


Hydraulic Pumps
Air Injection
Collector
a
b
Rigid Pipe
Buffer
Flotation Block
Miner Vehicle
Semi-Submerged Surface Platform
Miner Vehicle
c
d

Four systems for mining manganese nodules. *The first to be designed was the continuous line bucket system (a), in which a series of dredge buckets is attached to a cable that hangs in a loop from one or two surface ships. As the cable is dragged across the seafloor, it is rotated so that successive buckets scrape nodules off the bottom and bring them to the surface. In recent years, however, the mining industry has shown more interest in automated systems that would use compressed air, pressurized water, or electric pumps. In one such system, the surface vessel would tow a collector along the seafloor (b). In another, patented by the Ocean Minerals Company, a remote-controlled miner vehicle would crawl along the bottom scooping up nodules (c). The vehicle would crush the nodules to a slurry and pump them through a hose to an intermediate station called a buffer, which in turn would feed the slurry to the surface ship through a rigid pipe. The flexible power line and hose could be kept out of the vehicle's path by a flotation block. The futuristic acoustically controlled French system would include a fleet of unmanned, untethered "shuttles," each of which would gather nodules, deposit them at a semisubmersible platform, and swoop down to the seafloor for another load (d).*

Source: Oceanus, Fall, 1982

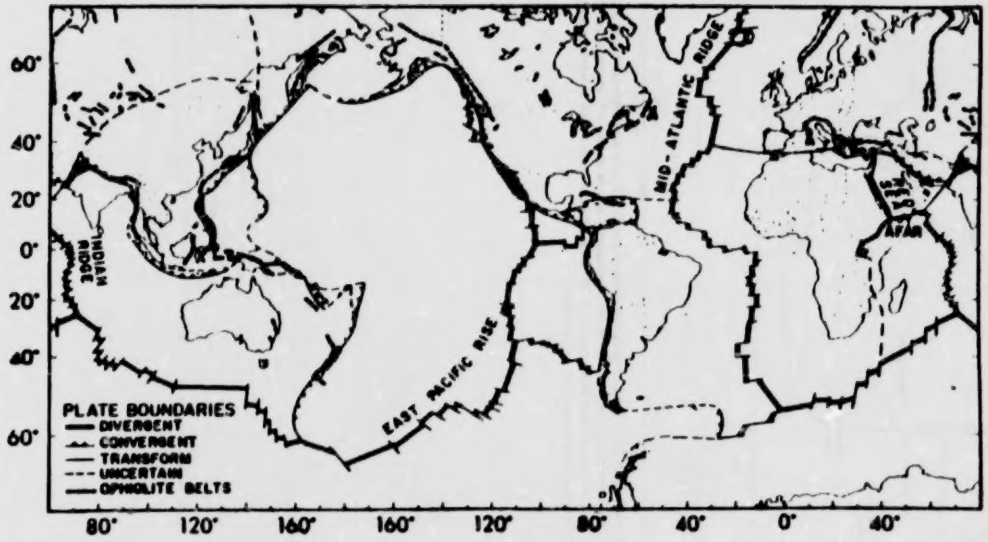
Figure 5


Northern
Mariana
Islands
Guam
Wake
Island
Midway Island
Johnston
Island
Hawaii
Palmyra Atoll
Howland
Island
Jarvis Island
American
Samoa
Puerto
Rico
V. Virgin
Islands
2000 KILOMETERS
300 NAUTICAL MILES

Exclusive Economic Zone (EEZ) of the United States, Commonwealth of Puerto Rico, Commonwealth of the Northern Mariana Islands, and United States overseas territories and possessions (outlines of map are approximate). Acreage now deemed within the U.S. EEZ includes: United States proper, 2.787 billion acres; Commonwealth of Northern Mariana Islands, 0.290 billion acres; territories and possessions, 0.839 billion acres.

Figure 6

Plate Boundaries.


60°
40°
20°
0°
20°
40°
60°
80°
120°
160°
160°
120°
80°
40°
0°
40°
MID-ATLANTIC RIDGE
RED SEA
AFAR
EAST PACIFIC RISE
INDIAN RIDGE
PLATE BOUNDARIES
DIVERGENT
CONVERGENT
TRANSFORM
UNCERTAIN
OPHIOLITE BELTS

Source: Rona, Peter. Criteria for Recognition of Hydrothermal Mineral Deposits in Oceanic Crust. Economic Geology, Vol. 73, No. 2, March-April, 1978, p. 135-160.

Figure 7

Deep seabed mining perturbations and environmental impact concerns

MINING PERTURBATIONS

		BENTHIC IMPACT		SURFACE DISCHARGE	
	STATUS OF CONCERNS*	COLLECTOR CONTACT	BENTHIC PLUME	PARTICULATES	DISSOLVED SUBSTANCES
CONCERNS WITHOUT POTENTIAL FOR SIGNIFICANT OR ADVERSE IMPACTS	Low Probability of Impacts	Light from collector	Nutrient or trace metal increase Oxygen demand	Bacteria growth deplete oxygen Alter phytoplankton species composition Affect fish Zooplankton mortality and species composition and abundance changes in plume Trace metals entry into food web	Trace metals effects on phytoplankton Nutrient increase cause phytoplankton blooms Airlift caused embolisms
	Impacts Not Yet Resolved	Not Applicable	Not applicable	Pycnocline accumulation	Not applicable
	Potentially Beneficial Effects	Additional food supply for bottom scavengers	Not applicable	Bacteria increase food supply for zooplankton Filterfeeding zooplankton fecal pellets clean up plume	Not applicable
	Certain Impact Without Significant Adverse Effects	Not applicable	Not applicable	Increased turbidity reduce productivity	Not applicable
CONCERNS WITH POTENTIAL FOR SIGNIFICANT OR ADVERSE IMPACTS	Certain Impacts	Destroy benthos in and near track	Not applicable	Not applicable	Not applicable
	Unresolved Impacts	Not applicable	Blanket benthos; dilute food supply away from mine-site sub-areas	Affect fish larvae	Not applicable

*NOTE: Status of concerns is to be verified during demonstration-scale mining system tests, prior to commercial mining

ATTACHMENT

EEZ Mapping and Nonenergy Minerals Research

Although numerous federal agencies are, or are expected to be, involved in mapping the EEZ and researching nonenergy offshore minerals, the following summary of activities focuses on the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the Minerals Management Service (MMS), the Bureau of Mines, and the National Science Foundation (NSF).

The respective responsibilities of NOAA and the USGS in conducting a joint program for bathymetric surveying and data analyses of areas of the EEZ are set forth in a Memorandum of Understanding (MOU) signed in April, 1984. NOAA's primary responsibilities include surveying, mapping, oceanographic analysis, and the storage of data. USGS's primary responsibilities include defining the sea floor geology and geological processes, as well as characterizing and quantifying its energy and mineral resources.

National Oceanic and Atmospheric Administration

In 1984, NOAA began a program of systematic mapping of the EEZ, in cooperation with USGS. The initial focus of the program is on the west coast EEZ. Thus far surveys have been conducted off Northern California and Oregon. In 1986, the west coast surveys are expected to continue, and surveying of the cobalt-rich manganese crust areas off Hawaii will begin. By FY 1987, NOAA plans to be operating off Alaska and along the east coast.

The two NOAA ships currently operating on the west coast are the Davidson and the Surveyor, the former is equipped with the Bathymetric Swath Survey System used for shallow water mapping and the latter is equipped with a multi-beam survey system (SEABEAM) for deepwater surveys. In FY 1985, the incremental costs incurred by NOAA to conduct the bathymetric surveys amounted to $1,741,000; ship time was 140 days for the Surveyor and 137 days for the Davidson.

By the end of Fiscal Year 1986 NOAA plans to bring into operation another vessel, the Discoverer, equipped with the deepwater survey system for west coast activities. In FY 1987, NOAA plans to equip another vessel, the Oceanographer, with the deepwater survey system, and use it to survey the U.S. east coast. Equipping these two vessels will cost about $1.1 million per vessel.

NOAA's research on polymetallic sulfides, known as the hydrothermal vents program, is conducted through its Pacific Marine Environmental Laboratory in Seattle, Washington, and at the Hatfield Marine Center in Newport, Oregon. This research effort is designed to improve understanding of the physical, geochemical, and biological processes occurring at seafloor spreading centers; and to provide a framework to investigate the potential for the commercial recovery of PMS deposits.

NOAA's operational plan for hydrothermal venting in FY 1985 consisted of a three-part program to: (1) survey the Gorda Ridge and determine the presence of active hydrothermal venting ($900,000); (2) conduct water column sampling surveys over three known vent sites as part of a long-term vent effluent monitoring program ($800,000); and (3) conduct a photogeologic survey on Axial Volcano in the Juan de Fuca area as an initial step in establishing a long-term measurement program ($300,000). In addition to the photogeologic survey, a cooperative program with scientists at the Oregon State University is being undertaken to image the volcano's internal plumbing system using seismic techniques. The trend in NOAA's hydrothermal vents program on west coast spreading centers is moving away from reconnaissance surveys and is focusing more on vent monitoring.

Recently, while concluding an experiment on spreading rates and hydrothermal activity in the Atlantic, NOAA scientists found an active high temperature vent field with associated polymetallic sulfides and biological communities.

The House-passed FY 1986 Commerce appropriations bill, H.R. 2965, includes $1,000,000 for NOAA research on polymetallic sulfides, while the measure recently reported by the Senate Committee on Appropriations includes $2,000,000 for such research. The program was funded at a level of $800,000 in FY 1983, and at $2,000,000 in each of fiscal years 1984 and 1985.

NOAA's Sea Grant program has sponsored about $50,000 per year of research during each of Fiscal Years 1982-85 relating to the West Coast PMS deposits or vent biological communities. Examples include: development of technology for long-term monitoring of events at the seafloor; and studies of the hydrogen sulfide-eating bacteria (the bacteria may be commercially useful for cleaning up industrial waste streams containing sulfur compounds).

Sea Grant also funded about $100,000 per year of research during each of Fiscal Years 1982-84 for exploration for seamounts near Hawaii and associated geological, physical, oceanographic, and biological studies.

U.S. Geological Survey

The USGS, through the Offshore Geologic Surveys program of its Energy and Marine Geology Branch, supports EEZ baseline corridor assessments and research on the formation of marine energy and mineral deposits. In FY 1985, USGS funding for offshore geologic surveys and mapping related to the EEZ totaled about $10.2 million; in FY 1986, $13.2 million is expected to be appropriated for these activities. In addition, in FY 1985 funding for USGS's offshore hard minerals investigations amounted to about $4,000,000 (including approximately $2,500,000 for PMS research, $1,000,000 for analyses of cobalt-rich crusts, and $500,000 for studies on offshore phosphate and placer deposits).

In FY 1984, USGS funded activities included the completion of a GLORIA survey of the Pacific EEZ off California, Oregon, and Washington, covering 250,000 square miles. Currently, the R/V Farnella, a British research vessel, is conducting a survey of the deep waters of the Gulf of Mexico, covering over 150,000 square miles by the end of 1985.

To synthesize the present state of knowledge on the geology and geologic framework of the EEZ, the USGS is preparing the Continental Margin Maps (CONMAP) Series. The first set of the compilation map series for the Atlantic is expected to be completed by the end of 1985. Eventually, the series will provide maps of twenty large areas of the EEZ with overlays depicting marine resources, seismicity, and volcanism.

Following up on information gathered by NOAA on hydrothermal venting in the Gorda Ridge, USGS scientists recently completed a cruise leg in the south end of the ridge on the S.P. Lee, conducting seismic surveys and recovering fist-size metalliferous nodules. In addition, in FY 1985 placer deposits, including titanium deposits, were surveyed in the Mid-and South Atlantic.

Pursuant to the April, 1984 MOU, USGS has provided $315,000 in FY 1984, and $650,000 in FY 1985 to NOAA to support bathymetric surveys, and expects to transfer $300,000 to NOAA in FY 1986 for that purpose.

Minerals Management Service

The Minerals Management Service (MMS) asserts jurisdiction over the leasing of nonenergy minerals on the EEZ, pursuant to section 8(k) of the Outer Continental Shelf Lands Act (OCSLA). Interior's program for hardrock mineral leasing activities in U.S. offshore areas was announced in January, 1982. To develop a leasing program for cobalt-enriched manganese crusts, polymetallic sulfides, and other nonenergy minerals, MMS established the Office of Strategic and International Minerals (OSIM) in Long Beach, California. Since FY 1984, OSIM has been funded at an annual level of approximately $2,000,000.

In early 1984 two joint Federal/State task forces were formed to evaluate the environmental, economic, and engineering potential of ocean mining in various areas: (1) the Hawaii Task Force, to focus on the cobalt-rich manganese crusts in the EEZ surrounding the Hawaiian Archipelago; and (2) the Gorda Ridge Task Force, to consider the development of nonenergy minerals in the Gorda Ridge.

On March 28, 1983, MMS issued a notice of intent to prepare an environmental impact statement (EIS) on offshore nonenergy minerals leasing on the Gorda Ridge. Although a draft EIS was released in December, 1983, no decision to proceed with the preparation of a final EIS for the Gorda Ridge area has been made. The OSIM expects the Gorda Ridge Task Force to forward a recommendation to the Secretary of the Interior late in 1985 or early in 1986 regarding the continuation of the leasing process.

A draft EIS for the exploration and possible recovery of cobalt-rich manganese crusts in the Hawaiian EEZ and off Johnston Island is expected to be completed in 1986. The completion of a final EIS and a decision to proceed with leasing is not expected to occur before 1987.

Pursuant to an Advance Notice of Proposed Rulemaking (ANPRM) issued in December, 1984, MMS is currently circulating for review draft regulations to govern strategic, critical, and other minerals exploration activities in the EEZ. An ANPRM concerning the issuance of new regulations to govern the leasing of such minerals on the OCS was issued in April, 1985, the comment period closed in August, 1985, and leasing regulations are now being drafted. Additionally, in January, 1985, MMS issued a Call for Information for potential leasing ot strategic and nonenergy minerals in the EEZ and OCS on a case-by-case basis.

Bureau of Mines

At the present time funding for research on marine minerals at the Department of the Interior's Bureau ot Mines is limited. In 1982, research conducted on polymetallic sulfide samples verified that the same metallurgical processes used for land-based minerals are applicable to these marine minerals.

The Administration has requested about $650,000 in FY 1986 for the Bureau for studies on metallurgy and beneficiation, mining equipment, and economics focusing on the Pacific cobalt-rich manganese crusts.

National Science Foundation

The NSF does not have a marine polymetallic sulfide program element per se. However, NSF's Submarine Geology and Geophysics, Marine Chemistry, and Biological Oceanography programs support research on various elements of oceanic rise systems, including hydrothermal systems, the processes that control the exchange of heat and chemical elements between seawater and oceanic rocks, and the unique fauna and ecological systems associated with active vent fields. Grants for such research are estimated to amount to a minimum ot $2.6 million in FY 1986.

Ms. **Mikulski**. Now, the committee would like to call its first panel, those involved in the actual operation of the Ocean Minerals Program; Mr. Paul Wolff, the Assistant Administrator; and Mr. Conrad Welling of the Ocean Minerals Co., to give us the private sector dimension. If you gentlemen would come up, please.

We welcome you to our panel. And, Mr. Wolff, as the lead agency, and therefore the leading spokesman on this issue, why don't you begin and then we'll hear from Mr. Welling and then proceed with questions?

Mr. **Wolff**. Thank you, Madam Chairwoman. I have submitted testimony for the record, and with your permission I would read a brief excerpt from it, and then show some of the examples of the chart work which we are doing in the EEZ. I have with me Mr. Lawless, who has been associated with the program since the beginning.

Ms. **Mikulski**. Well, with unanimous consent your entire testimony will be entered into the record. Hearing no objection, please proceed with your summary.

Mr. **Wolff**. Thank you, ma'am.

STATEMENT OF PAUL M. WOLFF, ASSISTANT ADMINISTRATOR FOR OCEAN SERVICES AND COASTAL ZONE MANAGEMENT, NOAA

Mr. **Wolff**. Since it became law in 1980, the Deep Seabed Hard Minerals Resources Act has worked well. NOAA's performance under this law is considered to be successful. We recommend continuing these functions as an important Government activity.

Four exploration licenses for sites in the eastern equatorial Pacific were issued in 1984 to multinational companies with U.S. partners. Site conflicts were resolved after a year of private arbitration, as outlined in NOAA's regulations.

Working with the State Department, NOAA designated the Federal Republic of Germany, France, the United Kingdom, and Japan as reciprocating states. Their mining sites will be recognized in return for recognition of U.S. sites. Discussions are underway with Italy, which has enacted a seabed mining law.

The current minerals market and technological outlook make it very unlikely that commercial deep seabed mining activities will be proposed for a number of years. But because of the long-lead time for industry, it is important that a regulatory framework be in place. NOAA has been developing draft commercial recovery regulations and plans to propose draft recovery regulations for public comment in the next few months. NOAA endorses continued support for the act.

In the area of the EEZ, NOAA became active in 1983 and began surveys in 1984. Detailed bathymetric surveys of the EEZ are needed for the following reasons: Like any new territory, it should be explored and its resources estimated; the data from the surveys will form the basic framework for more detailed exploration by the private sector; the bathymetric data is important for global ocean models for improved weather forecasting. These models will also use ocean satellite observations to predict ocean currents.

Our EEZ work is being done cooperatively with the U.S. Geological Survey of the Department of Interior. Products from the EEZ survey effort will be field survey charts, 1:50,000 scale, with 10-meter contours of water depth, and 50-meter contours of horizontal accuracy; bathymetric maps, 1:100,000 scale, 20-meter contours; and all the data will be in the form of a computer digital data base.

NOAA is synthesizing the best available scientific information for display in comprehensive atlases and nationwide data bases on U.S. waters out to the EEZ boundary. This data is important to analyze resource use conflicts and compatibilities, and to identify research needs. For example, it is useful for decisions on offshore oil and gas leasing, ocean waste disposal, and oil spill response.

NOAA's research program seeks to predict and locate hydrothermal regions and associated mineral deposits. We have discovered more extensive mineral deposits than suspected, and the potential effects on both the chemical and heat budgets of the ocean from the large influx of hydrothermal fluids at the seafloor vents. Using state-of-the-art deep side-scan sonar tows, a high resolution photographic image of the seafloor is possible. This chart, produced by NOAA research, represents the type of site specific analysis which the research community and the private industry can conduct, complementing NOAA's bathymetric data.

I'd like now to show some of the reasons why this research is necessary. I have here three charts, small sections of the charts off the coast of California. This chart is the best that's available to the public at the present time. This second chart is what is available—if you enlarge a portion of that chart. And this is what we get with our Seabeam system, which is a horizontal system worked from the surface which produces the detailed contours which are necessary to do any real exploration.

The two advances in science that have made this possible are the global positioning system, which enables us to locate our ships within 50 meters horizontally any place and the mapping system which produces depths with 10 meter accuracy.

As the ship worked off California, this is the picture of the seafloor that was developed by the computer. Several of these canyons were not known to exist before. They're important for fisheries and for mineral research and for geology, and for any use that anybody's going to make in an engineering fashion on the seafloor.

After that data goes through the computer it comes out in a more detailed picture, which is readily useable by the engineering people. And our newest development, which is done by the NOAA Pacific Marine Labs—Dr. Bernard in Seattle. We took the maps which we had made from the surface sounder, and then we flew the deep sonar vehicle right down through the ridge area where we suspected that the mineral deposits were. And then we combined all the data in the computer and that produces this mosaic, which is quite striking. It's new geology, if you got involved in mining or any other activity on the floor, this is the kind of data and detail that you will need.

It's not proposed that the Government collect this data, except to develop the techniques. We do propose to do the routine surveying because that is a big project, it's a typical NOAA project, and it involves monitoring, it involves doing a project with the same technology from beginning to end, and is a real Government function. The detailed work of this fashion is much too expensive to do except in areas where there are known items of real interest on the seafloor.

NOAA's interest in this matter also extends into the possibility of pollution. We're concerned the water column and with the processes on the ocean floor. It's instructive to look at our latest bathymetric map which is off the east coast. And you can see there that the white area represents the shelf. And if we consider that the extent to which the ocean is sensitive to man's activities is a function of two things; the distance from the shore—the sensitivity is greatest right at the shoreline and decreases as you go seaward—and the water depth. If the water is shallow, things which man do can effect the ocean. If the water is 12,000 feet deep, there is no evidence that anything man has ever done in history has effected the ocean. Of course the dilutive properties of that big body of water are obvious.

So, the point I'm trying to make here is that the sensitivity of the offshore area in the EEZ to man's activities is much greater on the east coast than on the west coast. The shallow area has a width of only 2 or 3 miles off Monterey. In other words, if you go out more than 2 or 3 miles you're in deep water. So, the sensitivity of the map on the west coast to man's activities offshore is much less than what it is off the east coast.

And as we begin to evaluate some of these effects on the environment, it's going to be necessary to have this detailed survey.

Thank you, Madam Chairwoman.

Ms. Mikulski. Thank you very much, Mr. Wolff, for a marvelous overview of your work and the potential in this most important area. Mr. Welling, we'd like to hear now from the private sector, what you think your future is in this area.

[Statement of Mr. Wolff follows:]

Statement of Paul M. Wolff, Assistant Administrator for Ocean Services and Coastal Zone Management, National Oceanic and Atmospheric Administration, Department of Commerce

My name is Paul M. Wolff, Assistant Administrator for Ocean Services and Coastal Zone Management of the National Oceanic and Atmospheric Administration, and I am pleased to testify today on the Deep Seabed Hard Mineral Resources Act, and on NOAA's implementation of the Act. My purpose will also be to provide the subcommittee with an update on NOAA's activities with respect to deep seabed hard minerals and Exclusive Economic Zone (EEZ) surveys.

The Act dates from 1980; it sets up the legal structure for U.S. companies to explore for and recover deep seabed manganese nodules—alternative, stable source of strategic metals. NOAA issues licenses to explore for deep seabed hard minerals, and permits to mine the minerals commercially. It also funds research related to potential environmental impacts from seabed mining activities.

NOAA consults with the Secretary of State and other departments and agencies, and designates as reciprocating states other nations with compatible seabed mining programs that recognize U.S. authorities. These arrangements work to prevent conflicts among mining operations.

NOAA's efforts have encouraged development of a new seabed mining industry in the United States which operates in a responsible and environmentally sound manner. We have provided the necessary degree of certainty to U.S. industry while also recognizing the need for flexibility to encourage innovation.

In 1982, NOAA received initial applications for exploration licenses from the four multi-national consortia with U.S. industry participation. These "pre-enactment explorers" under the Act are Ocean Minerals Company, Ocean Management, Inc., Ocean Mining Associates, and the Kennecott Consortium. Pioneer companies also applied for licenses in the Federal Republic of Germany, the United Kingdom, and

France. Subsequently, a law was enacted in Japan, and an application was filed there.

The initial applications all were filed in the Eastern equatorial area of the Pacific Ocean known as the "Clarion-Clipperton Zone," roughly between Central America and Hawaii. All proposed sites conflicted with at least one other proposed site. Pursuant to NOAA regulations and agreement with the other governments, the companies entered into a private arbitration agreement to resolve conflicts. The negotiations continued for over a year, but eventually all conflicts were resolved by private settlement agreement. Meanwhile, NOAA received application amendments to reflect the progress of negotiations.

In early 1984 the four consortia submitted final license applications conforming to the agreements. In late 1984 NOAA issued the four exploration licenses with accompanying terms, conditions and restrictions. The licensees are pursuing the exploration consistent with these licenses.

The prime objective of exploration is to delineate the important features of a promising area, to permit evaluation as a mine area. The key is to identify and assess commercially sufficient nodule reserves. In addition, factors bearing on the difficulty of mining will be examined. These include the detailed morphology of the seafloor, the distribution of obstacles, and the physical properties of seafloor sediments. Exploration activities consist of sampling and remote sensing. Nodules and sediment samples from the seafloor are collected with free fall grab samplers, dredge baskets, box cores, gravity corners, and free fall corers. Remote sensing gathers data on the nodules, water depth, sediment, and topography, using echosounders, acoustic side-scan and sub-bottom profilers, and television and stereo camera systems. Other activities include analysis of data received from other consortia during the conflict resolution negotiations, assessment of the world metals market, market strategies, and financial planning. Mining tests are not presently authorized, although the licenses could be amended to include such activities.

During 1985, NOAA approved one application for a license revision. We expect other license revision requests as licensees' plans and activities evolve. In addition, NOAA receives annual reports from licensees and monitors their activities under the licenses.

Besides activities associated with exploration licenses, NOAA has begun to develop the commercial recovery regulations called for in Section 308 of the Act. Although such activities are not anticipated for a number of years, there is an extended period of planning required for companies to scale up to commercial level operations. It is useful, therefore, to establish relatively soon the regulatory framework for commercial recovery.

During 1983, NOAA solicited public comment on subjects to be addressed in the regulations, through a series discussion papers, meetings, and workshops. This included consulting with other Federal agencies, industry, environmental groups, Congressional committee staff, and states. Over the last year NOAA has developed draft commercial recovery regulations; we plan proposed regulations for public comment in the next few months.

In addition to its basic research on seafloor processes, NOAA has maintained a modest research program specifically to support licensing and permitting decisions. The focus is primarily on environmental issues related to decisions on commercial recovery permit applications.

In its programmatic Environmental Impact Statement (EIS), NOAA has identified the three potential seabed mining effects with possible significant impact as (i) destruction of benthos in and near the collector track; (ii) blanketing of benthic fauna and dilution of food supply away from the mine site; and (iii) surface plume effect on fish larvae. Current emphasis is on potential benthic impacts, because relatively less is known about it and because research has already revealed that some of the other potential impacts now seem improbable. Other studies have examined disposal of processing wastes, foreign siting of on-land processing facilities, the nature of the mineral resources, and the economics of seabed mining operations. These allow NOAA to judge better the effects of regulatory actions on operations.

NOAA has worked with the State Department on the international aspects of seabed mining, pursuant to Section 118 of the Act. The first international agreement was signed in September 1982 by those countries which then had seabed mining laws (the United States, Federal Repubic of Germany, United Kingdom and France). It established procedures for site conflict resolution, and criteria for resolution of conflicts by the governments if private efforts failed. In August 1984, the United States signed an agreement with these countries, plus Belgium, Italy, Japan, and the Netherlands to avoid conflicts among the parties' mine sites, and to consult on matters related to seabed mining. The Administrator of NOAA designated the

FRG, France, United Kingdom and Japan as reciprocating states, thereby recognizing their mine sites in return for recognition of U.S. sites. Since then, Italy has enacted a seabed mining law, and NOAA is working with the State Department and Italy on reciprocating state designation.

NOAA will continue monitoring to assure compliance with the terms of licenses. There will be further license revisions proposed as licensees refine their plans in response to technology and metals markets. There may also be new license applications. We envision continued studies to assist in making the regulatory determination for commercial recovery permits. For these reasons, we endorse continued Congressional support for the Act.

With your permission, Madam Chairwoman, I would like now to discuss related NOAA programs to survey and characterize the U.S. Exclusive Economic Zone, and to continue our research on the natural processes occurring on the seafloor. I have brought with me, as you requested, illustrative materials, primarily in the form of recent charts and maps. As these are too large to submit for the record, I hope you, the other Members of the Subcommittee, and your staffs will have time to examine them.

On March 10, 1983, President Reagan issued a Presidential Proclamation establishing the 200-mile EEZ adjacent to the territorial sea. To support this Proclamation, the Department of Commerce has established a goal "to determine the character and resources of the 200-mile exclusive economic zone by 1990."

There are at least three reasons to survey the EEZ. First, the area is subject to the United States' sovereignty and should be explored and its resources estimated; detailed seafloor characteristics of the 3.3 million square mile EEZ are unknown except for limited research exploration at particular sites. Second, the large area data bases developed from such surveys may form the basis for detailed private sector exploration, leading toward use of these U.S. resources. Third, detailed bathymetry off our shores may be important to improved weather forecasting on a nation-wide basis. The configuration of the seafloor may be an important component of accurate air-sea interactive models could improve marine forecasts and warnings, and more accurate 3–5 day forecasts over land.

The improved accuracy of satellite positioning systems, developments in multibeam sonar systems, the application of heave-pitch-roll sensors to ships motion, and improved computer and plotter capabilities have all combined to provide significant improvement in our ability to define seafloor topography. Horizontal positioning with 50 meter standard accuracy is now available through the Global Positioning System (GPS). Depth determination to 10 meter accuracy is available from multibeam sounders.

Bathymetric maps will be particularly useful in locating areas for detailed studies of active vent sites where polymetallic sulfides may be forming, such as along the Gorda Ridge off Oregon. The maps will identify seamounts such as those found off Hawaii containing cobalt/manganese crusts, and identify sand ridges where valuable placer deposits exist on our continental shelves. They also could be useful in regional environmental impact studies prior to mineral or oil and gas leasing.

Coordinated effort in ocean satellite measurements is expected to produce a large increase in ocean observations from space between now and the early 1990's. The list of these satellites includes: Geosat, Topex, Gravsat, ERS–1, and others. The application of this data to ocean models would be facilitated by a data set containing ocean depths on a fine grid. Whenever ocean currents flow over irregular bottom depths, disturbances in the flow are generated, many of which reach to the surface.

NOAA's objective is to complete detailed bathymetric surveys of high priority areas of the EEZ. These surveys are being conducted in cooperation with, and with the partial financial support of, the U.S. Geological Survey under a Memorandum of Understanding between the two agencies. The first test surveys began in 1984 off California. This year operations were expanded to an area off Oregon where the Ocean Drilling Project of the National Science Foundation, and research by universities, NOAA and the Department of the Interior are focused. By next fall, the first surveys off Hawaii are to begin, later to be followed by work off Alaska as multibeam shiptime becomes available.

The intended products of the EEZ Bathymetric Mapping Program are: (1) field surveys at 1:50,000 scale, with 10 meter contours and an accuracy on the order of tens of meters; (2) bathymetric maps published at 1:100,000 scale with 20 meter contours, available through the existing NOS distribution system; (3) digital bathymetric data tapes and copies of 3.5 kHz records, available on microfilm; and (4) improved bathymetric fishing maps which combine detailed bathymetry, obstruction data, and bottom characteristics.

In addition to this effort to acquire new data on the EEZ, NOAA is synthesizing available scientific information for display in a series of comprehensive environmental atlases and data bases on the waters of the contiguous U.S. out to the boundary of the EEZ.

NOAA is the only Federal agency currently developing these nation-wide data sets to analyze existing and potential oceanic resource-use conflicts and compatibilities. They are used extensively by the private sector and by Government in such areas as offshore oil and gas leasing, ocean waste disposal (including incineration), and oil spill response. Components of this effort include:

Regional Data Atlases.—NOAA compiles, synthesizes, and displays in a series of comprehensive data atlases the best available scientific information on selected characteristics of the EEZ by major region. The east coast was completed in 1980; the Gulf of Mexico was completed in 1985; the Bering, Chukchi, and Beaufort Seas Atlas is in production and to be completed in 1986; and the west coast and Gulf of Alaska Atlas is in production and to be completed in 1987. Major data categories include physical environment, biotic environments, living marine resources, economic activities, environmental quality and jurisdictions. Each atlas contains about 150 maps at a scale of 1:4,000,000.

National Atlas.—This 1986 product will compile, synthesize, and display best available, comprehensive scientific information on indicators of the health and use of coastal waters on a single base map (1:12,000,000) that covers the entire coastline of the U.S. About 40 individual maps and accompanying text will explain and interpret the importance of these indicators.

National Estuarine Inventory and Atlas.—This project focuses on 92 large and medium-sized estuaries that account for 90 percent of the freshwater inflow and 90 percent of the estuarine water surface area in the contiguous U.S. It will be complete in 1986.

National Coastal Pollutant Discharge Inventory.—NOAA maintains the data base and computational system for estimating 17 types of pollutant discharges from all point, nonpoint, and riverine sources into estuarine, coastal, and oceanic waters of the contiguous U.S., from the head of estuaries to the seaward boundary of the EEZ.

These products will help other agencies and the general public to understand the resources of the EEZ and how they are used. They are also directly useful to NOAA in a range of activities from planning oceanographic research to responding to individual hazardous spills with trajectory models.

Recent discoveries of extensive active hydrothermal regions indicate that:

(1) Mineral deposits, notably polymetallic sulfides, are more extensive than previously suspected, and more concentrated than manganese nodules with respect to some metals;

(2) There is an extensive and highly complex biological community associated exclusively with the vents;

(3) The chemical budget of the ocean may be profoundly affected by the influx of dissolved and particulate materials; and

(4) The heat budget of the oceans and its influence on certain oceanic current systems may be affected.

This past summer NOAA's field work on the Juan de Fuca spreading center west of Portland, Oregon, employed a state-of-the-art deep tow side-scan sonar. The sonar image provides, in effect, a very large scale but high resolution photographic image of the seafloor. This image is "groundtruthed" with a deep-tow 35mm camera to definitively correlate the sonar signatures with specific geologic features. Then the sonar data can be processed at varying scales of resolution, and key features color-enhanced. The sonar images reveal very subtle yet geologically important structural trends.

Madam Chairwoman, this completes my testimony on NOAA's deep seabed and EEZ activities. I would be pleased to respond to your questions.

STATEMENT OF CONRAD WELLING, OCEAN MINERALS CO.

Mr. **Welling**. Thank you, Madam Chairwoman. I wish to submit my written testimony for the record.

Ms. **Mikulski**. With unanimous consent, so approved.

Mr. **Welling**. And I will just excerpt from the written testimony. I am senior vice president of Ocean Minerals Co., a consortium of Lockheed, Cyprus Minerals, Billiton International Metals, and BKW Ocean Minerals, both Dutch companies.

I am here as chairman of the Undersea Mineral Resources Committee of the American Mining Congress. Most of the U.S. companies involved in ocean mining are members of the American Mining Congress and have representatives on the Undersea Mineral Resources Committee. And I am here to speak for the members of this subcommittee.

I think that in order to give a better understanding of the ocean mining area, it might be worthwhile to give a brief background of it. I've been involved in this area for over 20 years and have led the activity at Lockheed.

A combination of factors in the 1960's led to the great development and expenditures by a large number of companies in this area. And expenditures to date have been devoted to the manganese nodules. In the United States it has exceeded a half a billion dollars. So that quite a bit of effort has been put in this area.

But the two factors that led to this tremendous effort was one, a great scientific postwar effort by the oceanographic community that led to the realization that the manganese nodules was a great resource. The second factor was the postwar continued strong development of the metals market, which continued right on through until the mid to late 1970's. As such, it became apparent, at least from the background, that there was a need to develop new sources of metals, and the manganese nodules certainly provided that approach.

However, a few years ago, around the end of the 1970's, early 1980's, the market plateaued, and as a result the number of new mines brought on the market stream exceeded the demand, and therefore depressed the metals market. And we have been in a depressed state since that time, and we don't know when it might recover.

However, the fact is, that having spent a tremendous amount of money in research and development, the mining companies felt that they should stay the course with the expectation that the market will recover within a relatively short period.

Now, another factor is the tremendous increase in the scientific knowledge of the ocean floor gained as a result of the oceanographic activities. This has led to a discovery of other sources, potential sources of minerals, such as the polymetallic sulfides and others. We believe that this is extremely important. But the point I want to make here is that it was the scientific discovery in the first place of the manganese nodules that encouraged industry to proceed in this area. And I'm sure that it's impossible to present a timing element on it, but I'm sure that the continued and the hopefully increased scientific work of the ocean floor will lead to other discoveries that will then enable industry to continue in a fashion that they did on the manganese nodules.

Now, the recent proclamation of President Reagan on the Exclusive Economic Zone is extremely important to the fledgling industry, because again it provided an incentive to that area of the ocean that had not been given a lot of attention in the past.

Regardless of the mineral knowledge we gain in the future, it is absolutely essential that the legal climate provide the necessary incentives to industry to obtain the high risk development capital. The Deep Seabed Hard Mineral Resources Act does provide this for the deep seabed. The Congress, after many years of debate, passed the Deep Seabed Hard Mineral Resources Act in 1980. Industry strongly supported this measure.

We are particularly pleased, Madam Chairwoman, with NOAA's administration of the act. We consider reauthorization essential to a continuation of a highly successful legislative endeavor. However, there is considerable reservation in industry about the adequacy of present laws and regulations concerning the minerals of the Exclusive Economic Zone.

In March 1983 the American Mining Congress took the position that the Outer Continental Shelf Lands Act, as amended, should be amended to provide a new hard rock, nonpetroleum, mineral resource legal regime generally similar to that in the Deep Seabed Hard Mineral Resources Act that was passed previously.

Let me repeat one part of the American Mining Congress declaration of policy. We support enactment of hard minerals legislation prior to issuance of the EEZ hard mineral regulations in order to provide a legal regime based upon hard minerals economic and technical data rather than on data related to development of oil and gas. There's a tremendous difference between oil and gas resources and hard mineral resources. The variations in hard rock mineral resources are tremendous compared to the variation in oil and gas resources.

Just prior to the adoption of that resolution, at a joint workshop for industry and Government on the Exclusive Economic Zone recently in Long Beach, CA in September, industry representatives took the position that the Outer Continential Shelf legislation is not appropriate for hard mineral leasing.

The American Mining Congress Undersea Mineral Resources Committee will shortly assemble a task force to consider drafting proposed amendments to the Outer Continental Shelf Lands Act, and to outline requirements for a new bill that would, among other things, explore possible alternatives to competitive bidding for the hard rock, protect investments at the exploratory stage, and seek ways in which to provide security of title.

Thank you very much, Madam Chairwoman, for this opportunity to present this testimony.

Ms. MIKULSKI. Thank you very much.

[Statement of Mr. Welling follows:]

STATEMENT OF CONRAD G. WELLING, SENIOR VICE PRESIDENT, OCEAN MINERALS CO.

Mr. Chairman and members of the Committee: My name is Conrad G. Welling. I am Vice President, Ocean Minerals Company, Santa Clara, California. In this position I am responsible for the planning, development and execution of the deep ocean mining program. Ocean Minerals Company is a partnership between Lockheed Systems Company, Inc., Ocean Minerals Incorporated and Cyprus Minerals Company. Participaing in Ocean Minerals Inc., are: Billiton B.V., and BKW Ocean Minerals B.V., both of the Netherlands; and Lockheed Missiles and Space Co., Sunny Vale, California.

I am here as Chairman of the Undersea Mineral Resources Committee of the American Mining Congress. Most of the U.S. companies that are participants in international ocean mining consortia are members of the American Mining Congress and have representatives on the American Mining Congress Undersea Mineral Resources Committee. As Chairman, I represent the members of the American Mining Congress that have an interest in deep ocean mining.

The American Mining Congress is an industry association that encompasses (1) producers of most of America's metals, coal, and industrial and agricultural minerals; (2) manufacturers of mining and mineral processing machinery, equipment and supplies; and (3) engineering and consulting firms and financial institutions that serve the mining industry.

Before I proceed, I believe a short background on deep ocean mining may be of help to this committee. A combination of factors in the 1960s gave a powerful impulse to the beginning of deep ocean mining development. One was the great increase in ocean floor scientific discoveries that led to the realization that manganese nodules existed in great quantities throughout the world's ocean floor. Second was the healthy post-war growth in the world market for the metals contained in these nodules, i.e., nickel, copper, cobalt and manganese. Even though the commercial grade nodules were at great depth, approximately 15,000 feet—5,000 meters—they existed right on the ocean floor, facilitating exploration and potential mining techniques. No other known ocean floor deposits, with the exception of oil and gas, come close in potential commercial value. In the past 20 years U.S. industry has spent approximately one-half billion dollars in exploration, mining and processing R&D to further its capabilities in exploiting the resource.

A few years ago the world metal market for nickel, copper, cobalt and manganese among other commodities slid into a recession from which it has not recovered. As a result it was no longer prudent for industry to spend the high risk capital, a billion or two, for further development. Therefore, industry has reduced considerably the previously planned expenditures and is in a holding mode. It may be as long as 10 years or more, hopefully less, before a good investment climate returns for the development of manganese nodules.

Knowledge gained about the spreading ocean floor and development of a new sonar mapping system, the Sea Beam, and the deep ocean manned submersible have led to new important discoveries. Associated with the spreading centers are hydrothermal vents producing polymetallic sulfides. There is no question that the vent discoveries could lead to extensive new discoveries and eventually have a great impact upon the supply of some metals in the future.

Continued ocean scientific research has revealed additional ocean floor resource potentials. Polymetallic sulfides, containing lead, zinc, copper and other metals, have been discovered in the hot thermal areas of the ocean floor spreading centers. Very little is known of the potential commercial value of these discoveries at this time. However, continued scientific exploration will, without doubt, provide the additional information so necessary for industry investment interest.

The recent proclamation of President Reagan on the Exclusive Economic Zone is extremely important to the fledgling ocean mining industry. The Exclusive Economic Zone is an area 200 miles seaward of the U.S. coastline. The proclamation approximately doubles the amount of land area under the economic control of the U.S. Our knowledge of the mineral occurrences in this area is practically zero. Hopefully, increased ocean scientific research, particularly of the ocean floor, will provide the knowledge so necessary for development.

Regardless of the mineral knowledge we gain in the future, it will be absolutely necessary that the legal climate provide the necessary incentives to industry to obtain the high risk development capital. The Deep Seabed Hard Mineral Resources Act does provide this for the deep seabed. The Congress, after many years of debate, passed the Deep Seabed Hard Mineral Resources Act in 1980. Industry supported that measure. Regardless of the mineral knowledge we gain in the future, it will be absolutely necessary that the legal climate provide the necessary incentives to industry to obtain the high-risk development capital. The Deep Seabed Hard Mineral Resources Act does provide such a legal regime for the deep seabed. We are particularly pleased Mr. Chairman, with NOAA's administration of the Act. We consider reauthorization essential to a continuation of a highly successful legislative endeavor. However, there is considerable reservation in industry about the adequacy of present laws and regulations concerning the minerals of the Exclusive Economic Zone.

In March of 1983 the American Mining Congress took the position that the Outer Continental Shelf Lands Act (43 USC 1331 et seq. (1953) as amended), should be amended to provide a new hard rock (non-petroleum) mineral resource legal regime, generally similar to that in the the Deep Seabed Hard Mineral Resources Act (30 USC 1401 et seq. (1980)).

The American Mining Congress, at its convention September 21, 1985, adoped the following resolution with regard to undersea mineral resources:

In the broad area of international trade and investment, special concerns revolve around the subject of undersea mineral resources. The oceans contain vast deposits of untapped mineral resources—manganese and cobalt, among others—that are of strategic and critical importance to the security and economy of the United States.

The wise development of these resources requires establishment of a stable and realistic regime under which investors with the necessary capital and skill can exercise their historic right of freedom of the high seas and pursue deep seabed mining in a secure, reasonable and nondiscriminatory manner.

We are persuaded that the proposed Law of the Sea Treaty provides none of these conditions, and we concur with the decision of the U.S. Government to reject the treaty. As an alternative we support the interim agreement on deep seabed mining signed among the reciprocating states and urge its implementation.

We support the President's 1983 proclamation of an Exclusive Economic Zone for the United States within 200 nautical miles of its coast, more than doubling the area of exclusive domestic resource jurisdiction.

With regard to hard minerals on the seabed within the EEZ, we support the cooperative efforts of the Departments of Interior and Commerce in performing the necessary preliminary seabed mapping and resource reconnaissance activities to facilitate policy formulation and industrial activity in the EEZ.

We support enactment of hard minerals legislation prior to issuance of the EEZ hard mineral regulations in order to provide a legal regime based upon hard minerals economic and technical data rather than on data related to development of oil and gas.

Further, the Deep Seabed Hard Mineral Resources Act of 1980 lays the groundwork for reaching broader agreement with a number of nations that share U.S. views and we urge initiatives in this direction.

The aim should be to establish a network of reciprocal rules and regulations among interested nations regarding their commitment to support and protect licensed deep seabed miners from diplomatic, legal and other challenges.

Let me repeat one part of it:

We support enactment of hard minerals legislation prior to issuance of the EEZ hard mineral regulations in order to provide a legal regime based upon hard mineral economic and technical data rather than on data related to development of oil and gas.

Just prior to the adoption of that resolution, at a joint workshop for industry and government on the EEZ in Long Beach, California, September 21, 1985, industry representatives took the position that the OCS legislation is not appropriate for hard mineral leasing.

The American Mining Congress Undersea Mineral Resources Committee will shortly assemble a task force to consider drafting proposed amendments to the OCS Lands Act and to outline requirements for a new bill that would, among other things, explore possible alternatives to competitive bidding for hard rock, protect investments at the exploratory stage, and seek ways in which to provide security of title.

We believe that there is a great deal that can be accomplished in the meantime with the joint cooperation of industry and governmental agencies that have jurisdiction in furthering mineral activity both in the EEZ and the deepsea.

We support the efforts of committees such as yours in furthering the development of minerals from the ocean.

Congressman Nick Joe Rahall (D-WV), in an address before the American Mining Congress in September 1985, said: ". . . I think we should focus some attention on the mineral potential we have here in the United States—both onshore and offshore. Something that I consider the 'wave' of the future is ocean mining."

Those of us who have been in this ocean mining business for many years agree with that statement.

We look forward to working with the Congress in furthering such development.

Ms. MIKULSKI. It's the purpose of this hearing not only to examine whether or not we should reauthorize this very modest program within NOAA—I believe it's about a million and some dollars—but this committee is holding a series of hearings on the oceans in the future to try and get a picture of what is the potential for the oceans and how we could, exercising the most prudent measures of stewardship, lay the groundwork for new ideas, new products, and new jobs. Of course, ocean minerals is one.

Mr. Welling, could you spell out for us what you think is an appropriate public sector role? You said that given marketplace gluts now of these minerals that there is no marketplace incentive for high-risk capital investment. But there could be embargoes, boycotts, any number of other things that could effect this from a national security purpose, and a variety of others also, mineral shortages developing in the world, that by the year 2000 we might need it.

What then do you think we should be doing to lay that framework for the future?

Mr. **Welling**. Well, Madam Chairwoman, there are several factors here that I think are extremely important. One thing is that I am a member of the Department of Interior's Strategic Minerals and Materials Committee. And we have been well briefed on a number of matters concerning the possible shortages of these materials.

The fact remains though that we would like to see the legal framework that will allow the risk capital to be made available, because we feel that's the best way to proceed. Now, there may be exceptions to this if there is some few critical minerals that the Government feels that they somehow or other have to obtain. But we feel that, in the long run, it is far better for us to go ahead in industry to raise the risk capital. But that can only be done, though, if the legal regime is in place.

And let me point out, though, furthermore, that we strongly support—and I want to emphasize this—we strongly support the increase in the scientific research being done, because it is only by that method that we will gain the basic knowledge that will allow us then to evaluate where we should put our investment capital.

And I feel that with the tremendous increase in scientific work, plus the improvement in the exploration technology that is now being evolved—and this should be supported incidentally—that we will make the discoveries. The ocean is a very vast place.

And in the many talks that I've given, in the recent years—and I've given these talks to the space engineers at Cape Kennedy—that we actually have discovered, really—I do not mean to overemphasize, a new planet in the solar system. The recent developments in oceanography from the postwar activity was the discovery of platetechtonics. It was one of the great scientific discoveries of all time.

And by this increased scientific knowledge that we're gaining as a basis, and with the legal regime in place that will support the risk-capital engagement, I am convinced that we may not have to wait this 10 years, that discoveries will come forth, and that this industry will then take off. It is only a temporary metals market that cut our effort down considerably from what it was.

Ms. **Mikulski**. Well, I think this committee shares with you the idea that a contemporary society needs a contemporary legal structure, and that some of our other mechanisms for either regulating or decisionmaking were not as modern as they should be.

This legal framework that you're talking about and the Outer Continental Shelf group that you're part of, are they developing the legal framework?

Mr. **Welling**. As I said before, we decided at Long Beach to put together a task force, the American Mining Congress, and to go ahead with recommendations to the Congress as well as other activities, and how we should proceed.

Ms. **Mikulski**. Well, let me say this both to you and to other private sector representatives who will be speaking this morning; we want to work with you. We want to create that framework for the future. We do not have the kind of hands-on experience that the private sector has had. You know what are winners and you know what are losers. You know what they're trying in some places of the world, where there have been successes and where there have been failures.

We would welcome those recommendations for such a framework, and then proceed in an orderly, rational way to conduct hearings and so on. But we want you to know we are committed to creating these frameworks.

Mr. **Welling**. Thank you very much, Madam Chairwoman. I appreciate those words.

Ms. **Mikulski**. Mr. Wolff, I have one question for you, and have others that we'd like to just submit for the record. Does the administration support the reauthorization of the Deep Seabed Act and the continued cooperation of NOAA's Ocean Minerals Program?

Mr. **Wolff**. Yes, ma'am. Dr. Calio, as the new Administrator, is initiating a study in this area. And, before reauthorization takes place, he may have some recommendations, but that isn't certain. But we do favor reauthorization. We think the program has been successful.

Ms. **Mikulski**. It certainly seems to be successful. And based on what we've heard about your performance, both you individually and the section that you head, you are really meeting the needs both for scientific research that's usable in universities, as well as in the private sector.

We look forward to further recommendations for improving this bill as we consider our reauthorization. Mr. Shumway, do you have any questions?

Mr. **Shumway**. Yes. Thank you, Madam Chairman. I was most intrigued by this very colorful picture that you submitted, Mr. Wolff, painted for us by computers. Are there any other nations in the world that have the technology that we have that makes a product like this available?

Mr. **Wolff**. Yes, sir. The basic technology that went into that has been around for 10 to 15 years. I know that the Federal Republic of Germany and France and Great Britain, and probably the U.S.S.R., have this capability.

Mr. **Shumway**. But you said that combining the different scans or measurements in making this kind of composite was revealing some new geographies, some new physical features that you didn't know were there.

In that respect, are you saying then that it's not new to other nations? Perhaps our own coastline would be new to them, but combining as we have is something they have done and know about?

Mr. **Wolff**. Well, no, sir. I misled you a little there. This combination is unique. But the three separate technologies that went into making this picture have existed for some time. This combination is unique and was put together by our research on that minerals area, where the plates are colliding off the coast there, and in the area of those underwater volcanoes. So, this combination is unique. But other countries can do this, and it's an open technology.

Mr. SHUMWAY. Had the United States entered into the Law of the Sea Treaty, would this kind of information then be shared with the international community under that treaty?

Mr. WOLFF. I'm not sure about the details of that treaty. NOAA does generally unclassified research, and this research will be reported in the open literature, so it will be available to everyone.

Mr. SHUMWAY. Well, I have some concern about the potential for this research having a sensitive nature to it. It would seem to me that some of these coastal areas would be very convenient hiding places for unwanted submarines or intruders from other nations.

Is there that security concern, and if so, are you doing anything to account for it?

Mr. WOLFF. NOAA is still negotiating on the data classification question with the national security people. NOAA's position is that we want to make the maximum of geophysical information available in open literature consistent with prudent national defense. We have a steering group that meets on these subjects monthly, and the discussions are heated.

Mr. SHUMWAY. Is the Navy part of that group?

Mr. WOLFF. Yes, sir.

Mr. SHUMWAY. And that's why the sessions are heated? They don't necessarily agree with open disclosures?

Mr. WOLFF. Some parts of the Navy. There's not a unanimous opinion.

Mr. SHUMWAY. I see. All right. Mr. Wolff, is there any difference in the management regime required for the developing of manganese nodules mining perhaps, as opposed to polymetallic sulfides or cobalt crusts?

Mr. WOLFF. Only to a limited extent. The manganese nodule areas are all in deep water and are all quite a distance away from the coast. So therefore, they come under the category of deep ocean, which is less sensitive to things that people might do there. As you get into some of the underwater volcanoes where these other deposits are, some of those are quite close to populated areas.

And so, our interest in the environmental impacts of what might be done in the water column there would be considerably greater.

Mr. SHUMWAY. Well, I thank you. As Congresswoman Mikulski has said, I likewise have a great deal of interest in this subject and would like to do anything that needs to be done from the Federal Government's point of view that might make enhanced research, and indeed someday profitable mining, possible on the seafloor.

And in that regard, Mr. Welling, we look forward to working with you and your consortium. Thank you.

Ms. MIKULSKI. Thank you very much. And we thank the panel for their testimony. We would now like to move onto the second panel to present an overview of ocean mining; Dr. James Broadus of Woods Hole Oceanographic Institution, Mr. Myron Nordquist, and Mr. Clifton Curtis, please.

Well, thank you very much for coming. And, Dr. Broadus, why don't you start us off?

Mr. BROADUS. Thank you Madam Chairwoman and members of the subcommittee.

STATEMENT OF JAMES BROADUS, ECONOMIST, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Mr. **Broadus**. I appreciate the opportunity to be with you today, and hope that my participation in this hearing will be of service to the subcommittee. I have submitted a very detailed prepared statement, and I will just attempt to hit some of the highlights of that in my presentation today.

Ms. **Mikulski**. Excuse me, I have a procedure. With unanimous consent your full testimony is entered into the record.

Mr. **Broadus**. Thank you. Let me clarify a little bit my institutional affiliation. I am a social scientist and economist in the Marine Policy and Ocean Management Center at the Woods Hole Oceanographic Institution. In that capacity I have been privileged, in large measure with sea grant support, to conduct a series of studies on such topics as the evolving economic structure of the international seabed mining industry, and economic and legal aspects of marine polymetallic sulfides. However, I am not associated with NOAA. Woods Hole is an independent, private, nonprofit research institution.

The views that I express today are my own, and do not necessarily represent those of either Sea Grant or the Woods Hole Oceanographic Institution.

As for my background, Madam Chairwoman, I have a Ph.D. in economics from Yale University and served for sometime as an economist in the Antitrust Division of the U.S. Department of Justice before joining the Marine Policy Center at Woods Hole.

Within the past decade it has become apparent that there are a variety of marine mineral prospects in the world's oceans and near-shore waters in addition to the abyssal manganese nodules that were the subject of so much economic effort and policy deliberation in the 1970's.

Marine mineral prospects can be understood as two different classes. The first are near-shore prospects and mineral resources in relatively shallow water. These do contribute to the world's economy, to the tune of about $590 million of revenues each year. The other class of marine mineral prospects are the deep-sea prospects. These include the manganese nodules, the hydrothermal polymetallic sulfides, and the so-called cobalt crust. All of the deep-sea deposits are long-term prospects at best, and none of them make any direct economic contribution to the world's mineral supplies at this time.

As for the marine polymetallic sulfides, in view of the remaining scientific uncertainties and the relatively unfavorable market conditions faced by the contained metals—which are primarily zinc, copper, and perhaps some amounts of silver—attempts to direct research on the marine polymetallic sulfide phenomena toward commercial development, such as the proposed minerals management service Gorda Ridge lease sale, appear premature. Marine polymetallic sulfides may someday become a valuable economic resource, but they are not now. Evaluation of expenditures on this prospect would still seem to be most appropriately based on scientific rather than commercial selection criteria.

It is, however, necessary to distinguish between the value of knowledge about the sulfide deposits and the resource value of the deposits themselves. Though the latter, the resource value, appears to be negligible, the former, knowledge about the processes that form the deposits, appears to be of substantial near-term value.

It is also useful to note that the large amount of work already conducted on development of the manganese nodules potential puts them in a separate category from the other two deep-sea prospects. The nodules are relatively far advanced, and we have a great deal of knowledge about how to recover them—the technology has been proved feasible, if not immediately economic—and about the nature of the resource itself.

My fundamental message, Madam Chairwoman, is simply this: Just as it is important not to be lured into false enthusiasms and unrealistic expectations about the newly emerging types of marine mineral prospects, it is also important to maintain a steady and realistic focus on the process of developing the manganese nodule resource.

In the last 20 years there has been a great deal of flux and change in the industrial activity directed toward development of manganese nodules. Examination of a time profile of expenditures of funds on exploration, research and development on the manganese nodules looks like a very steep mountain peak that starts to rise around the late 1960's, reaching peak levels of expenditures on the order of $100 million per year—in 1982 constant dollars—around 1977-78, and then dropping off dramatically after 1979 and 1980 to levels closer to about $10 million on a worldwide basis today. Most of the spending that is taking place on the technology and exploration today is being done by the Japanese.

Because of the great degree of change and reorganization that we have observed over the past 20 years of development of this industry, and that I think is necessarily going to be witnessed over the next 20 years of the development of this industry, I believe it is necessary to pursue very flexible policies and not to impose unnecessary rigidities on the ability of the commercial participants to organize themselves in the most effective way. Thankfully we're not in a crisis with these minerals, which gives us the luxury of time to be reflective, measured, and realistic in framing policies for their continued exploration and development.

In my prepared statement, Madam Chairwoman, I also address several other points which I believe might warrant the consideration of this committee. One concerns the prospects for the reemergence of substantial activity in marine mining research and development by commercial consortia and governmental parties. I think there are a number of conditions that indicate we can expect an upturn of activity in the relatively near term, perhaps peaking around the turn of the century.

Diligence requirements and the administration of diligence is an important related issue for your consideration. The current requirements in the Deep Seabed Hard Minerals Resources Act appear to be quite flexible and allow a great deal of discretion for the Administrator of NOAA to be flexible in the imposition of those standards. I think that is appropriate.

The design of optimal provisions for access, by private parties, to marine minerals prospects for exploration and development is a tough issue. It is one on which I've done some research with colleagues at Columbia, but we do not yet have any real clear conclusions to report other than it is a difficult question and one that is still wide open. Unless you simply want to attempt to maximize the immediate gains to the Government, in terms of revenues, and to shift the burden of risk entirely upon the potential commercial developers, the leasing system, such as that described in the Outer Continental Shelf Lands Act with bonus-bid front-end payments, is probably not appropriate. If you wish to pursue other goals, such as the promotion of scientific knowledge and learning about resources, alternative mechanisms deserve further consideration.

Finally, the question of agency responsibilities is one in which this committee might have some interest. As an economist, I'd just point out some advantages of competition. Some friendly rivalry between agencies can serve as a check on regulatory excesses, increase accountability, and provide diversity of information to policy makers. NOAA and Interior have shown significant progress in coordination of their efforts. In the early stages of development of these potential resources, where there is still a great deal of uncertainty, I urge this committee to consider that premature monoplization of all management responsibilities by a single agency could sacrifice the benefits of multiple-agency management at a time when these benefits seem most essential.

Thank you very much, Madam Chairwoman and members of the subcommittee. I appreciate your attention, and I'll be happy to answer any questions you might have on the points that I've raised.

[The prepared statement of Mr. Broadus follows:]

STATEMENT OF JAMES M. BROADUS, SOCIAL SCIENTIST, MARINE POLICY & OCEAN MANAGEMENT CENTER, WOODS HOLE OCEANOGRAPHIC INSTITUTION, WOODS HOLE, MA

Madam Chairwoman and Committee Members:

I appreciate the opportunity to be with you today and hope that my participation in this hearing on provisions for the development of marine mineral resources will be of service to the Committee. The basic role played by mineral resources and by technological innovation in the wellbeing of our national economy requires that questions of public policy toward development of marine mineral resources be approached with great care. The process of improving our understanding of marine minerals can contribute to scientific progress in general, and technological advances achieved in the process can find beneficial applications beyond marine minerals development. More generally, and perhaps most importantly, the expansion of the world's mineral resource base and the diversification of potential supplies can be a stabilizing influence that contributes to world peace.

Within the past decade, it has become clear that a variety of marine mineral prospects exist in the world's oceans and coastal waters in addition to the abyssal manganese nodules that were the subject of so much economic effort and policy deliberation in the 1970's. During the same period, we have witnessed an apparent collapse in the economic prospects and associated exploration, research and development (R&D) investments in the manganese nodules. I think that apparent collapse will be only temporary.

My fundamental message, Madam Chairwoman is simply this: just as it is important not to be lured into false enthusiams and unrealistic expectations about the newly-emerging types of marine mineral prospects, it is also important to maintain a steady and realistic focus on the process of developing the manganese nodule resource. Certainly, earlier expectations about the scale and pace of development of the nodule resource were greatly overblown. We should be careful, however, that the disappointment of those previous false hopes does not lead us into an equally unrealistic assumption that the manganese nodules have lost their promise and might just as well be forgotten. Thankfully, we are not in a crisis with these minerals, which gives us the luxury of time to be reflective, measured and realistic in framing policies for their continued exploration and development.

As a Social Scientist in the Marine Policy & Ocean Management (MPOM) Center of the Woods Hole Oceanographic Institution, it has been my priviledge over the past four years to participate in a continuing program of research on economic and legal aspects of marine minerals development. The three main objectives of the MPOM Center are: 1) to provide support and experience to Research Fellows interested in marine policy issues; 2) to provide opportunities for interdisciplinary application of natural science, technology and social science to marine policy problems; and 3) to research, evaluate and convey the information necessary for the development of local, national and international ocean policy. Before coming to the MPOM Center as a Research Fellow and eventually being appointed as the first Social Scientist on Woods Hole's resident scientific staff, I had received a Ph.D. degree in Economics at Yale University and served as an Economist in the Antitrust Division of the U.S. Department of Justice. The MPOM Center provides an excellent setting for applying the conceptual focus and analytic techniques of Industrial Organization and Natural Resource Economics to oceanic resources and activities. The basic subject of nearly all my recent and anticipated future economic research is: the process by which new resources (especially marine resources) are identified, developed and brought into productive use. Thanks in large measure to Sea Grant support, I have been able to conduct research on such topics as the evolving economic structure of the international seabed mining industry, economic and legal aspects of marine polymetallic sulfides, and the design of appropriate provisions for exploration and development access to marine mineral deposits. The remarks that follow are based on the results of those studies, though the views expressed are my own and do not necessarily represent those of either Sea Grant or the Woods Hole Oceanographic Institution.

In this statement, I will try to: 1) provide a brief survey of existing marine mineral prospects; 2) summarize the stage of development of the international seabed mining industry and explain why and when I expect a renewed show of activity from that quarter; 3) highlight the role of diligence requirements in affecting the quality of resource development; 4) provide some remarks on provisions for private access to areas of marine mineral potential; and 5) offer some brief observations on the progress of inter-agency cooperation and the place of multiple-agency involvement in the management of ocean minerals development.

It is helpful to think of marine mineral prospects as falling into two general classes: 1) deepsea deposits including manganese nodules, cobalt crusts, marine polymetallic sulfides (MPS), and perhaps certain deposits of marine phosphorites and mineral-rich sands; and 2) marine minerals that can be obtained from relatively shallow coastal waters, including aggregates such as sand, shell and gravel, phosporites, heavy mineral placer deposits, subseabed sulfur deposits, and precipitates and extracts such as salt, magnesium and bromine. As our interest today is concentrated on mineral deposits and marine mining, I will not discuss the precipitates and extracts further. While none of the deepsea mineral prospects are anywhere near production, it should be noted that some minerals have been produced from coastal waters of the world for many years. In other words, nonfuel marine minerals actually are produced offshore and do make a contribution to the world's economy. Marine minerals are not entirely a speculative resource. A necessary further point is that, relatively speaking, their current economic contribution to minerals production is not very important compared to the more conventional onshore sources of the same commodities.

Just to provide a scale of comparison as we look at the nonfuel minerals, consider the contribution of offshore hydrocarbons to the world's energy economy. It is, as you know, quite important. Total world offshore production of crude oil accounts for about a quarter of total world production, having nearly doubled its share from 16 per cent in 1970. Offshore natural gas output is over 20 per cent in the world total. Altogether, offshore hydrocarbons production accounts for well over $150 billion of annual revenues.

Exhibit 1 is a rough comparative summary of the current economic contributions made by the major marine minerals sources and prospects. As seen in Exhibit 1, almost 35 per cent of the value of offshore nonfuel mineral production comes from nearshore sand and gravel deposits. This amounts to something over $10 million in the United States annually and roughly $200 million on a global basis. That's less than one per cent of the estimated sand and gravel market on a worldwide basis. Holland, Great Britain and Japan are big users of offshore sand and gravel resources. Production is by sand pumping or dredging, sometimes operating many miles offshore. Technological constraints currently limit production to depths of less than about 40 meters. Because sand and gravel are relatively low value commodities, transportation costs are a major part of their delivered cost. In most cases, this confines the market reached by the product to a very localized area.

EXHIBIT 1

RELATIVE CONTRIBUTION OF OFFSHORE NON-FUEL MINERALS PRODUCTION
(Millions of US Dollars)

Commodity	Approx US Sales	Approx US Offshore	% US Sales Offshore	Approx World Sales	Approx World Offshore	% World Sales Offshore
Sand and Gravel a/	2,400	10	0.4	20,000	200	1.0
Shell/Calcium Carbonate	n	70	n	10,000	100	1.0
Sulfur b/	1,200	40	3.3	5,000	40	0.8
Tin	700	0	0.0	2,500	250	10.0
Phosphate Rock	1000	0	0.0	3,000	0	0.0
OFFSHORE PROSPECTS						
Phosphorites	-	0	-	-	0	-
Manganese Nodules	-	0	-	-	0	-
"Cobalt" Crusts	-	0	-	-	0	-
Polymetallic Sulfides	-	0	-	-	0	-
	Total US Offshore =	120		Total World Offshore =	590	

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n = Figure not calculated, not relevant or not available.

a/ Data for 1978. Total sand and gravel sales fell 34% 1978-82.

b/ Data for 1977. Offshore Frasch production has fallen steeply since.

Source: Adapted and updated from Glasby, 1979. "Minerals from the Sea." Endeavor n.s. 3.

Calcium carbonate represents almost a fifth of the total value of offshore nonfuel mineral production. US output is on the order $70 million annually. Globally, offshore production is estimated at about $100 million, which represents only one per cent of the world's total annual calcium carbonate output.

Sulfur has been recovered commercially since the early 1960's off the coast of Louisiana. Salt-capped sulfur domes in the Gulf of Mexico are mined by the "Frasch" technique, injecting hot water to melt the sulfur and using air pressure to force the melted sulfur to the surface. Recovery of waste sulfur from pollution control equipment in refineries and fossil fuel burners, however, may altogether replace Frasch-produced sulfur in the United States by 2000. Offshore production is now limited to a single operation, producing about 40 million dollars of revenues or about three per cent of the U.S. market. On a global basis, this offshore sulfur output represents less than one per cent of world production.

Placer deposits are another important depositional setting for offshore mineral occurences. Placers are beds of heavy minerals sorted, gathered and deposited by the action of waves or flowing rivers. Tin is the most important offshore placer resource currently being exploited. Large amounts of tin have been dredged for many years off the Indonesian "Tin Islands" and to the east of the Thai island of Phuket. Offshore tin mining originated around 1815 in tidal areas, although this was done almost entirely by hand. Marine dredging for tin placers off Indonesia began in 1911, but the use of modern bucket dredges began only about twenty years ago. Offshore deposits now represent about half the inventoried tin resources of both Indonesia and Thailand. The tin market is one in which nearly 20% of world supplies are smuggled around export or production controls and in which myriad small-scale illegal producers frustrate governmental efforts to regulate offshore production. On a global basis the tin market is about $2.5 billion, and about $250 million of that or more is produced offshore with dredges. Thus, offshore resources of tin account for around ten per cent of total world tin production.

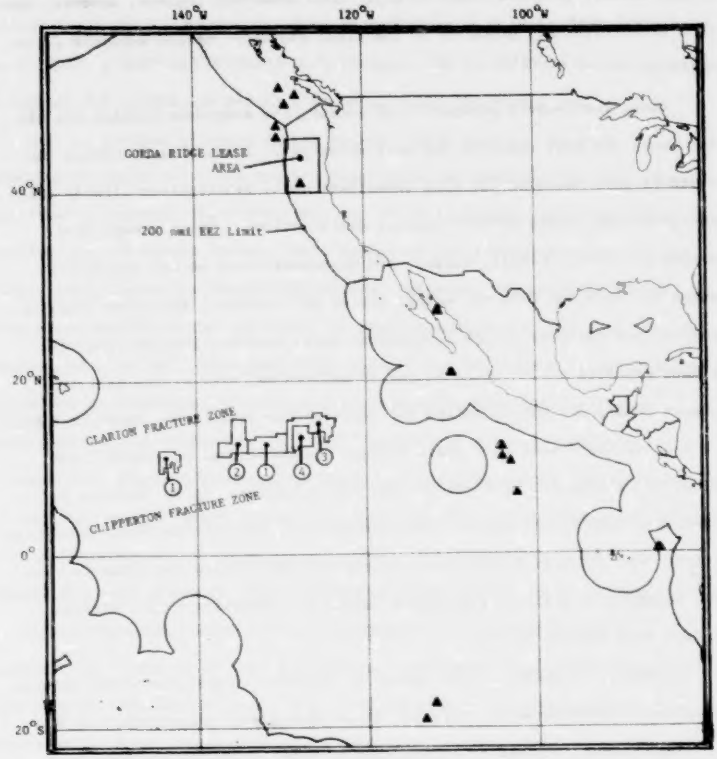
Gold is another offshore placer target. Over half of the gold production in South America's leading gold producing country, Colombia, comes from alluvial sources, which sometimes are the beginning of offshore placer deposits. In the United States, there appear to be reasonable prospects for economic gold placers in the EEZ off Alaska. Mineral rich sands in placer deposits are another potential source of such commodities as platinum, zircon, chromite and titanium. Important beach deposits of rutile and zircon are now being mined in Australia, but the evidence indicates that the associated offshore deposits are not as rich. Small amounts of titanium have been recovered from offshore ironsands in Japan and the Phillipines. Such mineral rich sands in ancient beach formations might turn out to be deepsea prospects also. A discovery of titanium concentrations in sands off the coasts of Virginia and Georgia has recently been reported by the Interior Department.

Another mineral target with both nearshore and deepsea occurrences is phosphorite deposits, a source of phosphate. Phosphate rock accounts for about a billion dollars of sales in the United States and is roughly a three billion dollar industry globally. The important onshore phosphate production in Florida comes from phosporites of marine origin, and there may be huge additional quantities of phosporites extending seaward from these deposits. In deeper waters, promising phosphorite deposits are extensive on the Blake Plateau in the US Atlantic EEZ, offshore California in the EEZ, and on the Chatham Rise offshore New Zealand. Like the highly publicized deepsea manganese deposits, the deepsea phosphorites occur as nodules or as pavements and are nowhere produced commercially. Some observers believe, however, that these phosporites may prove to be the first deepwater marine minerals to be exploited.

Among the deepsea prospects, of course, the manganese nodules are the best known and have received the most attention. I need hardly review the nature of this resource for this Committee: ample descriptions already exist throughout the record of your earlier deliberations. These prospective sources of nickel, cobalt, copper, and manganese occur on the seafloor at depths of 12-18,000 feet throughout the world's oceans. Extensive sampling programs and analyses of the accumulated data, however, indicate that the richest deposits may be found in the 13 million km^2 area of the Pacific between Hawaii and Mexico called the Clarion-Clipperton zone, shown in Exhibit 2. Nodules there seem to contain average concentrations of around 1.25% nickel, 1.0% copper, 0.25% cobalt, and 25% manganese. Again there is no offshore production of any of these commodities, but international industrial efforts over the past twenty years to explore and develop the resource have been staged at a scale of cumulative investment exceeding a half billion dollars (see Exhibit 3).

Credible estimates of the number of suitable "first generation" nodule minesites (3 million metric tons per annum throughput) range from 9 to 40. U.S. exploration licenses to define some of these sites further have been issued to four of the international consortia by the National Oceanic and Atmospheric Administration (NOAA). The locations of these sites are indicated in Exhibit 2. Licenses to other sites are being sought under the laws of foreign governments. Considerable overlaps still exist among the sites sought for exclusive development by various industrial entities, and two overlapping systems have emerged to resolve this problem and to provide security of

EXHIBIT 2


140°W
120°W
100°W
40°N
20°N
0°
20°S
GORDA RIDGE LEASE AREA
200 nmi EEZ Limit
CLARION FRACTURE ZONE
CLIPPERTON FRACTURE ZONE
①
②
①
④
③

DEEPSEA MINERALS SITES AND AREAS

Marine Polymetallic Sulfide Deposits = ▲

U.S. Deep Seabed Exploration License Areas =
① Ocean Minerals Company
② Ocean Management Incorporated
③ Ocean Mining Associates
④ Kennecott Consortium

EXHIBIT 3

CORPORATE INTERESTS AND ACTIVITIES IN SEABED MINING

CONSORTIUM MEMBER & SHARE	PARENT	NATIONALITY	PARENT'S ANNUAL R&D (1980-81) (millions)	ESTIMATED SPENDING TO DATE (a) (millions)	GENERAL FOCUS OF PARENTS' OPERATIONS	TECHNOLOGICAL FOCUS	STATUS AND COMMENTS
KENNECOTT CONSORTIUM (KCON): formed January 1974				$47.9	Petroleum production and trading; minerals production and metals trading (especially copper and gold); transportation; shipbuilding.	Metallurgical processing (led by Kennecott): "cuprion and ammoniacal leach" process; have tested a towed "vehicle" on a wire; holds patent on a self-propelled "tractor" and airlift system.	Virtually inactive since 1976. Have filed for two exploration licenses in both the U.K. and the U.S. for 191,000 km², by Kennecott through NOAA.
Kennecott Corporation (40%)	(SOHIO), BP	(U.S.), U.K.	$ 30.3				
RTZ Deepsea Mining Enterprises Ltd (12%)	Rio Tinto Zinc p.l.c.	U.K.	$ 23.1				
Consolidated Gold Fields p.l.c. (12%)	Consolidated Gold Fields p.l.c.	U.K.	$ 25.7 (1980)				
BP Petroleum Development Ltd (12%)	British Petroleum Company p.l.c.	U.K.	$201.0				
Noranda Exploration Inc. (12%)	Noranda Mines Ltd	Canada	$ 6.0				
Mitsubishi Corporation } (12%)	Mitsubishi Group (leader)	Japan	(b)				
Mitsubishi Metal Corp. }		Japan	(b)				
Mitsubishi Heavy Industries Ltd }		Japan	(b)				
OCEAN MINING ASSOCIATES (OMA): formed May 1974				$158.0	Petroleum production and trading; refined petroleum products; minerals production and metals trading (especially copper, lead, zinc, and others); steelmaking; other energy sources.	Deepsea Ventures (service contractor) has focused on a "towed dredgehead with radio" hydraulic recovery and "reduction and hydrochloric acid leach" process.	Successful prototype tests. Most active through 1982. Now curtailing sharply (all staff out in past year). Mining vessel scrapped, exploration ship laid-up. Holds U.S. exploration license for 136,000 km².
Essex Minerals Company (25%)	U.S. Steel Corporation	U.S.	$ 36.0				
Union Seas Inc. (25%)	(Union Minière, Union Minière S.A.), Société Générale de Belgique	Belgium	$ 9.3				
Sun Ocean Ventures (25%)	Sun Company Inc.	U.S.	$ 90.0				
Samin Ocean Inc. (25%)	Ente Nazionale Idrocarburi (ENI)	Italy	$162.0				
OCEAN MANAGEMENT INCORPORATED (OMI): formed February 1975				$49.2	Minerals production and metals trading (especially nickel and others); contract offshore drilling and support operations; steelmaking; construction machinery; banking; engineering; general trading; wire rope manufacturing.	Inco, West German, and Japanese companies have focused on towed sledge hydraulic recovery; Inco has focused on a "smelting and sulfuric acid leach" metallurgical process.	Completed planned feasibility study. Proved recovery technology, 1978. Curtailed work since 1979. Salzgitter withdrew from AMR group in 1980. Inco, SEDCO inactive. Holds NOAA exploration license for 155,000 km². AMR has filed separately in F.R.G.
Inco Inc. (25%)	Inco Ltd.	Canada	$ 37.9				
SEDCO Inc. (25%)	SEDCO, Inc.	U.S.	$ 12.4				
Arbeitsgemeinschaft Meerestechnisch Gewinnbare Rohstoffe (AMR) (25%)	{ Metallgesellschaft A.G. { Preussag A.G.	F.R.G. } F.R.G. }	$ 51.8 (c)				
Deep Ocean Minerals Company (DOMCO) (25%)	23 Companies led by Sumitomo	Japan	(b)				
OCEAN MINERALS COMPANY (OMCO): formed November 1977				$169.0	Missiles; space; electronics; aircraft manufacturing; petroleum production and trading; refined petroleum products, offshore dredging; pipelines.	Lockheed has patented a "remote-controlled, bottom-crawling" hydraulic recovery system; a "high temperature, sulfuric acid leach" metallurgical process has been examined.	Billiton withdrawing. Sun Ocean inactive. Recovery system failed to deliver nodules in at-sea test, 1978-79. Holds NOAA exploration license for 165,000 km². Lockheed now promoting CLB for other marine minerals.
Amoco Ocean Minerals Company (33%)	(Amoco Minerals), Standard Oil	U.S.	$190.0				
Lockheed Systems Company } (33%)	{ Lockheed Corporation	U.S.	$100.0				
Lockheed Missiles and Space Company }	{ Lockheed Corporation	U.S.					
Billiton B.V. (33%) } Ocean Minerals Inc.	{ Royal Dutch/Shell	Netherlands	$560.0				
B.K.W. Ocean Minerals B.V. ([illegible]) }	{ Royal Boskalis Westminster	Netherlands	$ 4.0				
ASSOCIATION FRANCAISE POUR L'ETUDE ET LA RECHERCHE DES NODULES (AFERNOD): formed 1974				$70.6	Oceanography; nuclear power; metallurgy; minerals production and metals trading (especially nickel and cobalt); shipbuilding.	AFERNOD has spread its focus: CLB, towed-sledge hydraulic, and the remote-controlled autonomous shuttlecraft (PLA). CNEXO now focusing on hydraulics.	AFERNOD inactive except to area claims. Holds exploration license under French law. R&D on PLA continues through GEMONOD, a new public group composed of CEA & IFREMER.
Centre National pour l'Exploitation des Océans (CNEXO) (10%)	French Government (d)	France	$ 63.7				
Commissariat à l'Energie Atomique (CEA) (25%)	French Government	France	N.A.				
Société Métallurgique le Nickel (SLN) ([illegible])	IMETAL, Elf Aquitaine	France	$ 3.3 (SLN)				
Chantiers du Nord et de la Méditerranée (CNM) ([illegible])	Schneider S.A.	France	$132.2 (1980)				
DEEP OCEAN RESOURCES DEVELOPMENT CORPORATION (DORD): formed September 1982				$40.1 (e)	General trading; steelmaking; shipbuilding; transportation; ferrous and nonferrous metallurgy; industrial machinery; chemicals; metals trading; cable manufacturing; pump manufacturing.	DOMA companies focused earlier on Masuda's CLB. Most recently under MITI's large-scale project, they have been developing a towed sledge, hydraulic recovery system. Metallurgical process unknown.	Most active group. Holds exploration license under Japanese law. R&D through MITI/AIST "large scale project." Projected 1982-90 budget approximately $80-90 million. KCON and OMI Japanese members included.
48 Companies (including the members of the Deep Ocean Minerals Association (DOMA)) that coordinate activities with MITI (b)		Japan	$ 61.0 (1982) (b)				

(a) Estimated total spending in 1982 dollars based on: Ocean Industry, 1981, U.S. Congress, 1981, and company sources.

(b) Japan's Ministry of International Trade and Industry (MITI) has made loans to Japanese companies participating in the multinational seabed mining consortia. For example, in 1976-78, approximately $9.75 million was loaned by MITI. MITI's affiliate Agency of Industrial Science and Technology (AIST) has initiated the development of a seabed minerals recovery system as a "large scale project." AIST's total 1982 Large Scale Project Budget (seabed mining and all other projects) is shown in the Parent's Annual R&D column for DORD.

(c) The figure is the 1982 budget for West Germany's Federal Ministry of Research and Technology (Bundesministerium für Forschung und Technologie or "BMFT"). BMFT has supported about 90% of AMR activities since 1975.

(d) CNEXO is in the process of merging with the French fisheries agency, ISTPM, to form a new agency called Institute Francaise de la Recherche et l'Exploitation de la Mer (IFREMER).

(e) Estimated nodule R&D spending by the Metal Mining Agency of Japan (MMAJ) in 1974-81 (GAO, 1983).

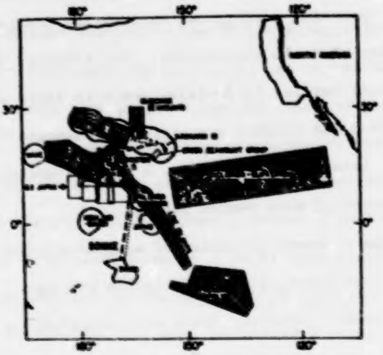
tenure. The system of reciprocating arrangements based on the domestic laws of certain seabed mining pioneer states made a significant advance in August, 1984 with the signing by the United States, Belgium, France, West Germany, Italy, Japan, the Netherlands and the United Kingdom of a "Provisional Understanding Regarding Deep Seabed Matters" (PU). Strong objections to this arrangement have been voiced by the USSR and other participants in the Law of the Sea process, but some parties to the PU (Belgium, France, Italy, Japan and the Netherlands) are also participants in the Law of the Sea Prepratory Commission process where some progress has been made recently in resolving overlapping claims. It is my belief that arrangements reached through efforts in these two separate entitlement procedures will contribute eventually to a convergence of the two regulatory regimes. Rather than burdening you here with the details of that case, however, I refer your staff to my June, 1984 article with Porter Hoagland in the San Diego Law Review, "Conflict Resolution in the Assignment of Area Entitlements for Seabed Mining."

Much progress has been achieved by the industrial consortia in developing technologies to explore for and recover the manganese nodules. The earliest efforts in recovery technology concentrated on the "continuous line bucket" system, but technical difficulties and advances on other fronts led to the virtual abandonment of that concept. For a time, the French program attempted to develop a recovery system based on autonomous shuttle vehicles, but that effort was largely unsuccessful and the French more recently have been working to catch up in the hydraulic lift technologies developed by the U.S. companies. In fact, all the consortia appear to have converged on the hydraulic lift recovery technology, and an active Japanese R&D program is also now aimed at advancing this approach. Detailed engineering models have been used by Sea Grant researchers at MIT and Texas A&M to estimate the costs and expected returns of seabed mining operations. Even with extremely optimistic assumptions, however, it appears that deepsea mining will require large initial capital expenditures ($1.1-3.7 billion) which at "normal" metal prices would result in inadequate returns on investment (17-25 % IROR) for such a risky venture. It should be recalled, further, that there is still great uncertainty about the operating conditions, engineering problems, and unanticipated costs that might be encountered. For example, there may be significant technological hurdles in devising means to avoid obstacles on the seafloor and in upscaling the complex prototype technologies to commercial levels of production. Later in my statement, I provide additional detail on the industrial development of deep seabed mining.

As interest in the economic potential of manganese nodules has been dwindling in the last five years, greater attention has been turned to the ferromanganese oxide "cobalt" crusts. These are geological cousins of the manganese nodules, but they occur in shallower water and as pavements or crusts firmly cemented to hard substrate. The most favored sites for cobalt-rich, thick encrustations seem to be seamount slopes and plateaus in 1-2 km of water in the Central Pacific, some within the U.S. EEZ as shown in Exhibit 4. Some groups of samples from this region have average cobalt content of around 0.9%, with a range of about 0.4% to 1.9%. Crust thickness appears to be extremely variable, but some sample averages exceed 2 cm. More information should be available soon from a data bank of existing information on crust occurrences now being assembled by Frank Manheim of the USGS in Woods Hole.

In fact, far too little is known about these mineral occurrences, or more importantly about how they might be commercially exploited, to support

EXHIBIT 4



Regional map showing principal known ferromanganese crust regions in the Central Pacific Ocean, along with area within which "prime" Pacific abyssal nodules occur.

SOURCE: Commeau, R.F. et al. 1984. "Ferromanganese Crust Resources in the Pacific and Atlantic Oceans." Proc. Oceans '84. Washington: NOAA, Ocean Assessments Division.

claims that they are economically important. A basic technical shortcoming is that the thin crusts are cemented fast to a hard-rock substrate, often in variable and rough terrain. Recovery of any of the barren substrate would diminish the effective, working metal grade of the recovered bulk of material. No method is known by which the crusts can be selectively recovered in quantity without some substrate material, though the USGS has recently advertised for proposals to develop such techniques for sampling purposes. Certainly no known methods exist to recover the material on a commercial scale. The Minerals Management Service (MMS) has begun the process leading to lease sales of prospective cobalt crust areas around Hawaii. Cobalt is the smallest market for any offshore prospect. In the United States it is about $120 million per year. Globally it is less than a billion dollars per year; and, again, there is no production from offshore sources.

Advances in deepsea exploration technology such as multibeam sonar, underwater photographic and electronic imagery transmission, robotics, and deep submergence vehicles have permitted the first-hand verification and continuing refinement of geophysical theories that had for several years predicted the occurrence of hydrothermal metals deposits at oceanic crustal spreading centers. The exciting discoveries of marine polymetallic sulfides (MPS) deposits at both active and dormant hot vents thus rewarded years of earlier scientific work. Exhibit 5 summarizes the MPS deposits that have so far been identified. Their locations are noted in Exhibit 2. Some metal assays that have been obtained from a limited number of samples are indicated in Exhibit 6. The minerals of most interest in MPS are zinc, copper, perhaps lead (which in onshore experience is often a co-product with zinc), and perhaps silver and other precious metals.

EXHIBIT 5

LOCATION OF MARINE POLYMETALLIC SULFIDE DISCOVERIES: October 1985

Location	Project and Date	Type of Occurrence
EXPLORER RIDGE AREA 49°46'N, 130°16'W	CASM 3; CASM 4; SCHISM 1 May/June 1984	40 sulfide deposits over 8km ridge crest; faulted massive sulfide "lens" with Cu-rich base and Zn-rich top; southern sulfides inactive, degrading; northern sulfides inactive, but relatively intact; seven of the 40 deposits are larger than 50m by 100m by 5-10m thick
JUAN DE FUCA RIDGE AREA 49°N, 128°W (approx.) "near Vancouver Island"	Pacific Geoscience Center (Canada) September 1985	Sediment-hosted sulfides; in comparison with other MPS occurrences, this find may have "relatively" high Au and Ag grades
47°57'N, 129°06'W "Endeavor Segment"	MERGE October 1982; NOAA/Geol. Soc. Can. 1984	140 kg. of sulfide material; actively venting and inactive Fe-, Zn-rich sulfide structures
46°00'N, 130°00'W "Axial Seamount, Central Segment"	CASM August 1983	sulfide/sulfate chimneys
44°40'N, 130°22'W Vent 2, Southern Segment	USGS/U.Washington September 1981	12 kg. of massive sulfides dredged from one site
44°40'N, 130°22'W	USGS Juan de Fuca Study Group September 1984	sulfide deposits occur as fields of spires and chimneys at 3 vent sites along 6km segment; recovered sulfides typically more than 80 weight percent ZnS
GORDA RIDGE AREA 41°N, 127°30'W (approx.) "Escanaba Trough"	USGS, NOAA, OSU September 1985	Turbidite sediment-hosted iron sulfides dredged near intrusive body; small amounts of copper and zinc present; up to 5% organic carbon
GUAYMAS BASIN 27°20'N, 111°30'W	US Navy November 1977	hydrothermal talc deposit with pyrrhotite (FeS), precipitated around vent
27°01'N, 111°25'W "DSDP Site 477"	Scripps 1980	Kuroko-like sulfide deposits sampled from hydrothermal cones and pinnacles; petroliferous sulfide-rich mud

EXHIBIT 5 (CONT.)

Location	Project and Date	Type of Occurrence
11°N EAST PACIFIC RISE		
11°30'N, 104°W "Zone B"	CNEXO/COB: Cyatherm Program Jan-Mar 1981	active hydrothermal deposition and associated sulfide deposition
10°56'N, 103°41'W	WHOI: Protea 9 May 1984	Massive sulfides (approx. 300 tonnes) associated with fissure-collapsed lava lake immediately east of axial graben
7°N EAST PACIFIC RISE		
6°42'-44'N, 102°36'-38'W	CNEXO/COB: Searise Cruise Summer 1980	iron sulfides with small amounts of copper sulfide minerals; and ferromanganese and other oxides recovered
GALAPAGOS RIFT AREA		
0°47'-49'N, 86°04'-13'W	US Navy SASS; WHOI Angus/Alvin Programs 1976, 1977, 1979	photographic identification of sulfide deposits 20km west of Malahoff site; none associated with active hydrothermal vent fields
0°45.3'N, 85°49.5W "ALVIN Dive 1001"	GRAFZI Project 1980	visual discovery of sulfide precipitate field (inactive vents) extending 2km west of dive site; sulfides sampled
0°45'N, 85°50'W	NOAA: NOS Aug-Sept 1981	4 sites of massive polymetallic sulfide deposition mapped; represents "several million tons of sulfides"; largest is 1000m long, 35m thick, 150m wide; previously discovered sulfide (see above) located along same fault system, 2km east of these discoveries
20°S EAST PACIFIC RISE		
18°30'-33'S, 113°24.5'W; (also 21.5°S, ?°W)	GEOMETEP 3 March 1983	4 deposits near 18°30'-33'S, one near 21.5°S. The latter contains stockwork mineralizations as well as massive sulfides
20°06'-10'S, 113°42'-44'W	WHOI, Stanford, IPGP 1981	active high-temperature sulfide deposition fields; sulfide deposits photographed

EXHIBIT 5 (CONT.)

Location	Project and Date	Type of Occurrence
21°N EAST PACIFIC RISE		
20°54'N, 109°03'W Hekinian et al., 1980	CYAMEX: Project RITA Feb/Mar 1978	massive sulfides recovered by submersible CYANA
20°50'N, 109°06'W	RISE Expedition Mar-May 1979	sites of actively forming massive sulfide mineral deposits along EPR axis at high temperature springs in SW section of 7km strip with 25 vents; sulfide mound deposits occur slightly off-axis from cooler vents to NE of strip
20°48.2'N, 109°17'W "Green Volcano" or "Volcano B"	Scripps, Washington Univ. (St. Louis), Smithsonian 1982	volcano "B" up to 500 m^2 of varicolored sulfides sampled
13°N EAST PACIFIC RISE		
12°38'-54'N, 103°49'-104°01'W "Zone A"	Clipperton Cruise May-June 1981	"About 30" massive sulfide sites on floor of central graben; sulfides dredged with locally high concentrations of cobalt; sulfides more massive than any pyritic deposits dredged thus far from EPR
12°41'-53'N, 103°55'-58'W "Zone A"	Cyatherm Program Jan-Mar 1982; Geocyarise Feb/Mar 1984	20 active hydrothermal sites located along 20km ridge axis; 84 sites (possible under-estimate) of sulfide deposition found; average diameter less than 50m; largest are 80m long by 30m wide
12°43'N, 103°52'W "Seamount C" or "Clipperton Seamount"	Clipperton Cruise May-June 1981; Cyatherm Program Jan-Mar 1982; Geocyarise Feb/Mar 1984	800m by 500m by (3m) marine sulfide capped with ochreous oxidation products on western limb of an apron of seamount; estimated at 2 million tonnes; self-potential survey indicates that sulfides might be up to 15m thick in places; much hydrated silica

EXHIBIT 6

TABLE 2 Chemical Composition of Massive Sulfide Deposits from the Sea Floor at 21°N, East Pacific Rise, Juan de Fuca and Galapagos Spreading Centers

	21°N, East Pacific Rise					Juan de Fuca			Galapagos rift
	1	2	3	4	5	6	7	8	9
					percent				
Fe	14.7	20.2	30.7	4.0	0.61	2.10	41.4	13.8	44.1
Zn	34.9	29.5	41.8	1.7	0.12	51.0	2.57	46.9	0.14
Cu	0.30	1.0	0.20	0.10	0.25	9.06	0.04	0.25	4.88
Pb	0.01	0.07	0.20	0.06	<0.04	0.30	0.27	0.30	<0.07
S	31.8	30.7	34.9	4.6	0.74	32.6	48.3	36.8	50.2
SiO_2	<0.01	7.6	<0.01	40.4	58.4	0.15	<0.05	<0.03	<0.03
$BaSO_4$	19.0	<0.5	4.3	2.0	1.7	2.6	11.3	1.5	<0.1
Al_2O_3	0.3	0.11	0.77	0.04	0.08	0.06	0.15	0.15	<0.08
MgO	<0.08	0.07	0.06	0.06	0.16	<0.05	<0.05	<0.05	<0.06
CaO	<0.01	3.42	<0.01	45.1	37.9	0.15	<0.05	<0.05	<0.05
Sum	101.6	100.77	98.87	97.33	100.05	98.05	103.73	101.80	101.42
					ppm				
Ag	241	94	202	9.6	1.6	320	15	590	<10
As	485	770	215	13.2	1.2	235	430	411	135
Au	NA	0.17	<0.2	0.025	<0.2	<0.1	<0.1	0.13	0.05
B	<7¹	<7¹	<7¹	<7¹	<7¹	90¹	40¹	40¹	<7¹
Ba	6000	65	850	120	225	1,300	465	19¹	10¹
Bi	<0.5¹	2¹	<0.5¹	2¹	1¹	<0.2¹	<0.2¹	<0.5¹	<10¹
Cd	130	600	780	60	<20	1,080	8	490	<20¹
Co	<3.0	2.5	6	22	30	0.4	1.2	34	402
Cr	8	30	<30	<5	13	<4¹	12	<4¹	35
Cs	0.7	<3.0	0.6	<2	<0.7	<5	<5	<5	<5
Ga	3.5¹	10¹	21¹	1.5¹	<1.5¹	<30¹	<30¹	<30¹	15¹
Ge	50¹	<1.5¹	100¹	<1.5¹	<1.5¹	130¹	27¹	270¹	<1¹
Hg	2¹	<1¹	<1¹	2¹	2¹	3¹	<1¹	<1¹	NA
Mn	370¹	91¹	500¹	50¹	19¹	90¹	2,100¹	720¹	140¹
Mo	30	75	15	2	0.6	<1¹	30¹	8¹	170¹
Ni	2¹	9¹	2¹	<1.5¹	2¹	<4¹	<4¹	NA	2.1¹
Pd	0.001	0.002	0.001	0.001	0.001	<0.002	<0.002	<0.002	<0.002
Pt	0.002	0.002	<0.001	0.005	0.001	<0.005	<0.005	<0.005	<0.005
Rh	0.002	0.0010	0.0022	0.0007	0.0010	0.003	0.008	0.005	<0.005
Sb	45.0	15	38.9	0.2	1.4	19	0.7	34	1.8
Se	<0.4	0.2	0.25	<0.3	0.02	1	0.1	<1	<0.3
Sn	7¹	172	50¹	3	<5¹	<5¹	<5¹	30	100
Sr	200	9	10	3,085	2,570	130¹	30¹	<10¹	<1¹
Te	<1¹	2¹	<1¹	2¹	<1¹	<1¹	9¹	<1¹	NA
Tl	40¹	20¹	<1¹	2¹	<1¹	30¹	40¹	10¹	<5¹
U	6.0	1.3	0.1	<2.0	1.3	<7	2.7	30	1.0
V	4¹	<1.5¹	5¹	5¹	<1.5¹	<4¹	<4¹	<4¹	<4¹
W	1.0	<3.0	<3.0	<1.0	<3.0	<10¹	<10¹	<10¹	<10¹
Zr	6¹	<4¹	40¹	14¹	<4¹	<11¹	<4¹	25¹	<4¹

See Table 1 for sample numbers

NA = not analyzed

¹ Semiquantitative optical emission spectroscopy

The following elements are below their respective detection limits (ppm) for all samples (by semiquantitative emission spectroscopy): Na (2000), K (700), Ti (20), P (2000), Be (1), Ce (40), La (10), Pr (20), Nd (10), Sm (20), Eu (8), Gd (20), Tb (100), Dy (10), Ho (8),
(10), Yb (10), Li (20), Nb (8), Sc (1), Ta (400), Th (20)

SOURCE: Bischoff, J.L. et al. 1983. "Seafloor Massive Sulfide Deposits from 21°N, East Pacific Rise; Juan de Fuca Ridge; and Galapagos Rift: Bulk Chemical Composition and Economic Implications." Economic Geology 78 (1983): 1711-1720.

Too little is yet known about the nature of MPS to permit confident estimates of their economic promise, but I have attempted a first-order approximation of their current significance on the basis of: 1) accepted economic understanding of the dynamics of nonrenewable resource supplies; 2) projections of aggregate consumption of the contained metals; 3) projection of long-run alternative supplies; 4) informed speculation about the sources and relative magnitudes of costs and the relative pace of technological advance; 5) scientific modeling results on geographic, size, and grade distributions; and 6) expressions of commercial interest by profit-oriented firms. The details of this analysis are reported in my 1984 paper, "Economic Significance of Marine Polymetallic Sulfides," which I have brought along for your interest. The evidence examined so far suggests that MPS are still largely a scientific phenomenon with little current economic significance.

In view of the remaining scientific uncertainties and of the relatively unfavorable market conditions faced by the contained metals, attempts to direct research on the MPS phenomenon toward commercial R&D, such as the proposed MMS Gorda Ridge lease sale, appear premature. MPS may someday become a valuable economic resource, but they do not appear to be now. Evaluation of expenditures on MPS would still seem to be most appropriately based on scientific rather than commercial selection criteria.

It is important to distinguish between the value of knowledge about MPS deposits and the resource value of the deposits themselves. Though the latter may be negligible, knowledge about MPS appears to be of substantial (if hard to measure) value. Information on the genesis of mineral deposits and their settings can be critical to the success of exploration methods based on geologic inference. Close study of MPS mineralizations may also foster improved inferences about such basic mysteries as geotectonic processes and the globe's thermal and geochemical dynamics. Further, development of technologies to aid these scientific inquiries will have the spillover effect of generally advancing human capability to function in a hostile environment.

Summarizing the rough overview contained in Exhibit 1, we see that deepsea minerals still make no direct contribution to world metal supplies. Taken all together we have an annual revenue produced offshore from the various nearshore nonfuel mineral sources of roughly 590 million dollars. Compared to the annual value of offshore oil and gas production this represents about one third of one per cent. To gain additional perspective, consider a recent Internal Revenue Service (IRS) estimate of unreported economic activity in this country. The IRS estimates that U.S. flea markets account for $1.7 billion dollars of sales per year, or about 3 times the global annual revenues associated with offshore minerals.

All the deepsea marine mineral prospects, including manganese nodules, marine polymetallic sulfides (MPS) and the so-called cobalt crusts have long-range potential at best. They are still surrounded in uncertainty and will require considerably more study and investment before they can contribute to the nation's metal supply. Nonetheless, it is crucial to recognize that substantial progress has been made in the process of bringing metals from deepsea manganese nodules into our stream of supply. A much higher level of understanding and practical know-how has been achieved for the nodules than for the other deepsea prospects, in terms of both knowledge of the physical resource and technology development. For this reason, among others, I feel that the manganese nodules are in a distinctly different, and far more immediately promising, economic class than the MPS and cobalt crusts.

The fortunes of all economic activities tend to vary over time, and this seems to be especially true in the extraction of mineral resources. There is no reason to be surprised that the same kinds of cyclical instability that afflict even the most mature extractive industries might also periodically dim the prospects of one still in an embryonic stage. Yet, the basic economic conditions that led intitially to the creation of this nascent industry still favor its eventual success. Seabed manganese nodules still represent a bountiful and rich store of important metals, and one that has become increasingly well-understood. The technology for metals recovery from seabed nodules has been proved feasible (if not sufficiently rewarding for immediate application) and will continue to be improved.

Exhibit 3 summarizes the current status of the major international industrial seabed mining consortia. In addition to the groups included in this exhibit, exploration and R&D programs in seabed mining have also been mounted by the governments of India, China, South Korea and the Soviet Union. The currently reduced commercial interest in manganese nodule prospects is reflected in the estimated combined spending profile for the commercial consortia, shown in Exhibit 7. I have reconstructed these spending estimates from an extremely fragmentary published record together with spotty clues provided by industry sources. Nonetheless, I believe they give an accurate general impression of the scale and time profile of industry efforts. As seen in Exhibit 7, estimated seabed mining expenditures reached appreciable levels in the early 1970's, rose rapidly in the mid-70's to peak levels around 1978-1979 of nearly $100 million (constant 1982 dollars) per annum, and then fell dramatically to currently token amounts. Estimated cumulative industry spending since 1962, as shown in Exhibit 8, equals $635 million (1982 dollars). Roughly the same pattern of activity is reflected in Exhibit 9, which shows the time profile of patent issuances as revealed through a detailed patent search by my colleague Porter Hoagland.

EXHIBIT 7

ESTIMATED CONSORTIA EXPENDITURES
(1969–1984)

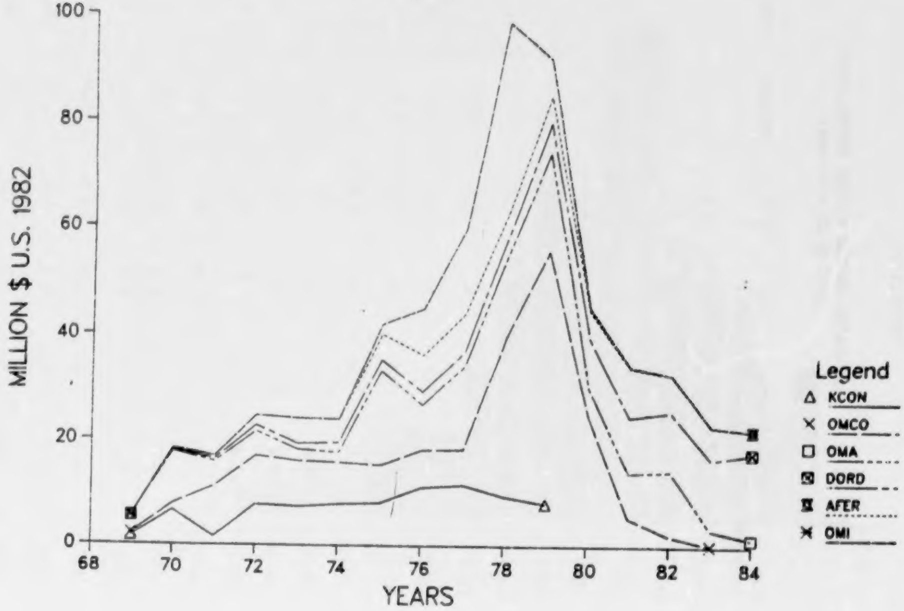


EXHIBIT 8

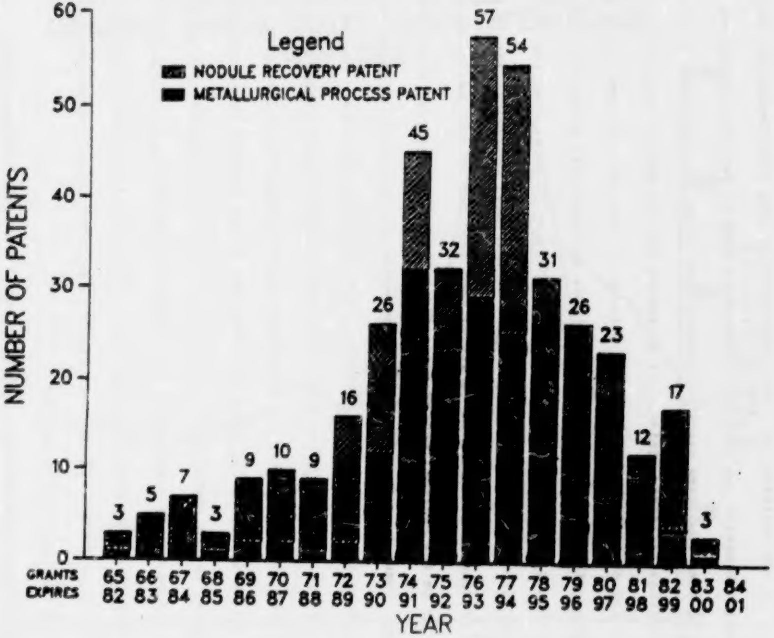
ESTIMATED SEABED MINING EXPENDITURES
(1982 $ US Millions)

YEAR (1962-64)	OMA (11.8)	KCON (2.5)	OMI (n.)	OMCO	AFERNOD	DORD	TOTAL (14.3)
1965	3.8	0.8	n.	0.6			5.2
1966	3.7	0.8	n.	0.6			5.1
1967	3.6	1.9	n.	0.6			6.1
1968	3.4	1.8	n.	0.6			5.8
1969	3.3	1.7	n.	0.5			5.5
1970	9.9	6.6	n.	1.2		n.	17.7
1971	4.7	1.6	n.	9.5	0.5	0.2	16.5
1972	4.6	7.7	n.	9.2	1.9	1.1	24.5
1973	2.2	7.3	n.	8.6	4.7	1.1	23.9
1974	1.9	7.8	n.	7.8	4.3	1.9	23.7
1975	17.8	8.0	1.8	7.1	4.7	2.1	41.5
1976	8.4	10.9	8.4	7.1	7.0	2.5	44.3
1977	15.8	11.4*	15.8	6.7	6.8	2.7	59.2
1978	14.7	9.2	35.3*	30.1	4.6	3.4	97.3*
1979	18.5*	7.9	6.9	46.9*	4.9	5.3	90.4
1980	5.2	n.	0.6	24.4	4.9	9.3	44.4
1981	8.4	n.	0.2	5.3	9.4*	10.4	33.7
1982	12.0	n.	0.1	2.0	6.9	11.1	32.1
1983	2.9	n.	0.1	0.2	6.0	13.1	22.3
1984	1.4	n.	n.	n.	4.2	15.9*	21.5
TOTALS	158.0	87.9	69.2	169.0	70.8	80.1	635.0

* - PEAK SPENDING YEAR

EXHIBIT 9

TOTAL SEABED MINING PATENTS WORLDWIDE 1965–1984



If one believes, as I do, that seabed mining investments are subject to cyclical behavior and that the investments made so far are not the end of the story, then something might be learned from these profiles about a cycle of activities in seabed mining. If we assume for the sake of conjecture that such cycles would be more or less regular in duration and symmetrical in shape (though with perhaps increasing amplitude as commercial production is approached), then we can infer a period of about 20 years from the profile in Exhibits 7 and 9. Admittedly, that is an extremely mechanical way to look at the process, but I think it is significant that the 20 year period conforms nicely to the cyclical period estimated by Professor Margaret Slade for the nickel industry. Oceanic nodule mines would not be solely nickel mines, though nickel is likely to contribute most to their revenues. As can be seen clearly in Exhibit 10, the historical rate of spending on seabed mining R&D has been closely related to the grade-weighted composite metals price for the metals contained in the nodules. When and as the markets for those metals recover, seabed mining will again be turned to as one promising avenue of R&D for future supply development. Returning to our mechanical projection of the industry's first cycle into the future, we might expect that spending will bottom out around 1988 and then begin a new climb upward to another peak around the turn of the century.

Such a mechanical projection is, of course, little more than a curiosity when taken alone. There are other reasons, however, to support this general scenario. One is the degree of governmental involvement in the seabed mining endeavors. As seen in Exhibit 11, the "market share" of governments in cumulative spending by the commercial consortia to date approaches one third. This share would be even larger if spending by the Soviet and Indian programs were included in the total. In most cases, governmental sponsorship appears

EXHIBIT 10

GRADE–WEIGHTED COMPOSITE METALS PRICE AND ESTIMATED ANNUAL SEABED MINING EXPENDITURES
1969–1982

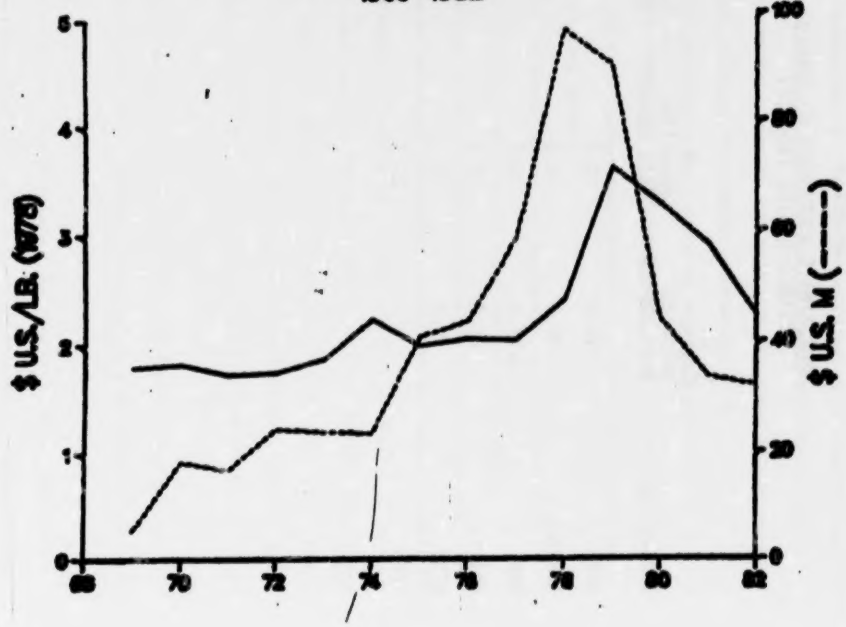


EXHIBIT 11

APPROXIMATE GOVERNMENTAL SHARES SEABED MINING INDUSTRY

Consortium	% Equity-Weighted Govt. Share	% Consortium "Mkt. Share"	% Government "Mkt. Share"
DORD	>95.0	10.5	10.0
AFERNOD	>90.0	10.9	9.8
OMA	<25.0	25.5	6.4
OMI	21.3	11.3	2.4
KCON	5.3	14.3	0.8
OMCO	0	27.5	0
TOTAL			29.4

to have been motivated more by interest in exporation of alternative long-run sources of materials supply and of advanced technology development than by prospects for commercially generated profits from the production and sales of metals. Accelerated efforts by national governments, or by government-subsidized corporations, operating on subcompetitive rates of return with extra-economic motivation, could well force the pace of development by commercial enterprises in order to protect their shares and position in a maturing industry.

Exhibit 12, in which spending by the Japanese national program is compared to the spending profile of the other commercial consortia, illustrates the kind of pull to recovery that might thus be generated. The nine-year Japanese technology development program, with a budget of about $80 million, is scheduled for completion in 1989. As seen in Exhibit 9, this is just about the same time that the great bulk of existing Western patents in the field will begin to expire. It also happens to be the period when many careful observers of the Preparatory Commission proceedings anticipate that enough ratifications will have been obtained to put the Law of the Sea treaty into force.

Both the composition and character of the embryonic seabed mining industry underwent substantial changes in its first twenty years of activity. This is reflected in the changing relative spending positions estimated in Exhibit 13. Similar flux can be expected over the next twenty year period. The existing seabed mining consortia do not appear to be very durable, and substantial reorganization and realignment should be expected in the industry during the extended preproduction phase. Some constraints to such reorganization should be noted, however. These include specific agreements to abstain from seabed mining activities outside the existing partnerships that

EXHIBIT 12

ESTIMATED CONSORTIA SEABED MINING EXPENDITURES (1969–1984)

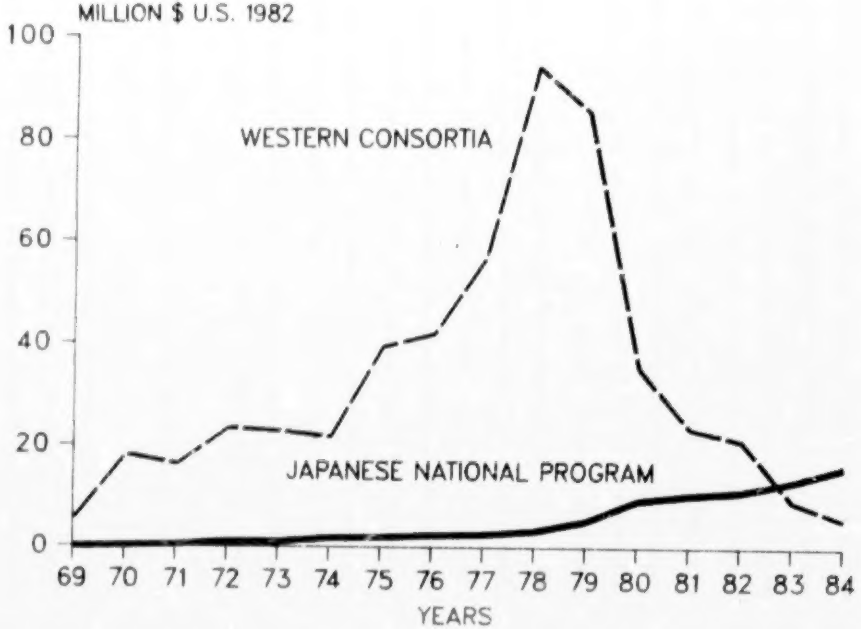
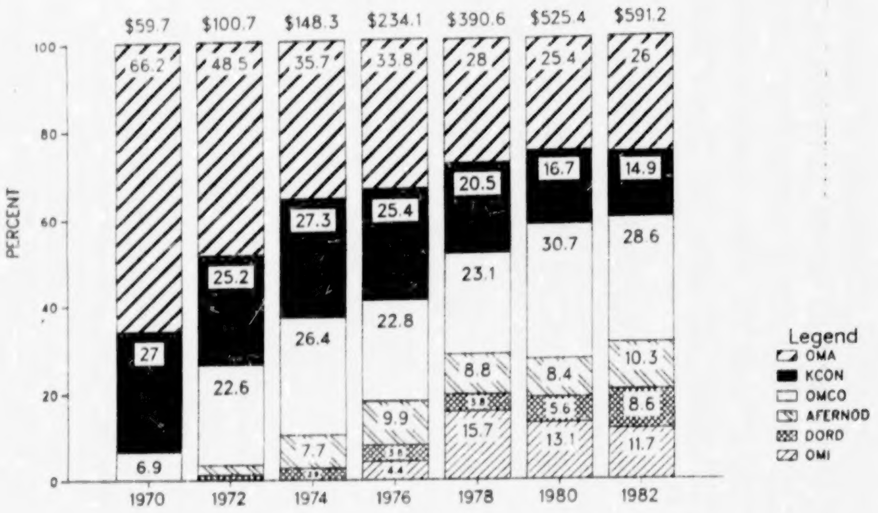


EXHIBIT 13

CHANGING SHARES:
ESTIMATED CUMULATIVE SPENDING FROM 1962
(M 1982 $ U.S.)



are written into some of the consortia partnership agreements and complications associated with reorganizing shares and tenure to minesite claims that are held in common by consortium members. Therefore, as the inception of seabed mining is likely to be many years in the future, substantial reorganization of the industry may not occur immediately.

The two most likely major reorganizations that might be expected in the industry in the relatively near term (5-10 years) are:

(a) possible formation of an all-European group built on the expertise of European members of various currently-existing consortia, and

(b) a pioneering joint venture between one or more of the technically advanced groups (such as Japan and/or France), a group of developing countries eager to commence earnings from Common Heritage resources and the Enterprise of the International Seabed Authority.

To accommodate and respond to such changes, and in view of the likely recommencement of serious activities within the decade, a high degree of flexibility seems in order for public policy and regulatory posture. This brings me to the question of diligence requirements. While the licensed commercial consortia try to wait for improved conditions to resume their development efforts, and when the locus of activity shifts more noticeably to those entities participating in the Law of the Sea process, I would not be surprised to hear increasing discussion of the role of diligence provisions in the domestic regulation of seabed mining. As it happens, the diligence provisions described under the Deep Seabed Hard Mineral Resources Act (DSHMRA) are quite flexible and give a great deal of administrative discretion to NOAA. This is, I believe, appropriate.

In this pioneering and experimental activity, where there is really no question of public royalties being foregone, strict enforcement of diligence provisions risks forcing the pace of seabed minerals development to an uneconomic degree. This could divert resources from more pressing and more profitable activities or it could needlessly force the premature abandonment of investments made and experience gained by the licensed firms. It could also increase the temptation for the industry to seek public subsidies, which I believe are unnecessary.

Another issue that will probably be receiving increased attention in the coming months concerns the best arrangements for governmentally-assured access by private firms to explore and develop minerals potential in promising ocean areas. I am just concluding a year of research on just this topic with colleagues at Woods Hole and Columbia University, but I must admit that there are as yet few clear conclusions to report. The question really seems to revolve on the goals of the government. If the goal is to shift risks entirely onto the would-be explorers and developers, then a bonus-bid leasing system such as that practiced under the Outer Continental Shelf Lands Act (OCSLA) is probably just fine. If more complex goals are to be pursued, however, including promotion of certain types of technological progress and certain areas of scientific advance, then alternative systems in which the government assumes a greater share of the risks and imposes less stringent initial demands on the companies might be appropriate. The Minerals Management Service has done some experimentation with alternative leasing systems within the basic bonus bid format, and these probably deserve more study. Other alternatives might include licensing provisions similar to those of the DSHMRA, prizes and awards, a patent system or preference right leasing, and direct exploration and development contracts. Suffice to say at this point that the issue of access provisions for marine minerals is a difficult and, so far as I know, unresolved issue. Here again, we do have the luxury of time for careful consideration and even some adaptive experimentation.

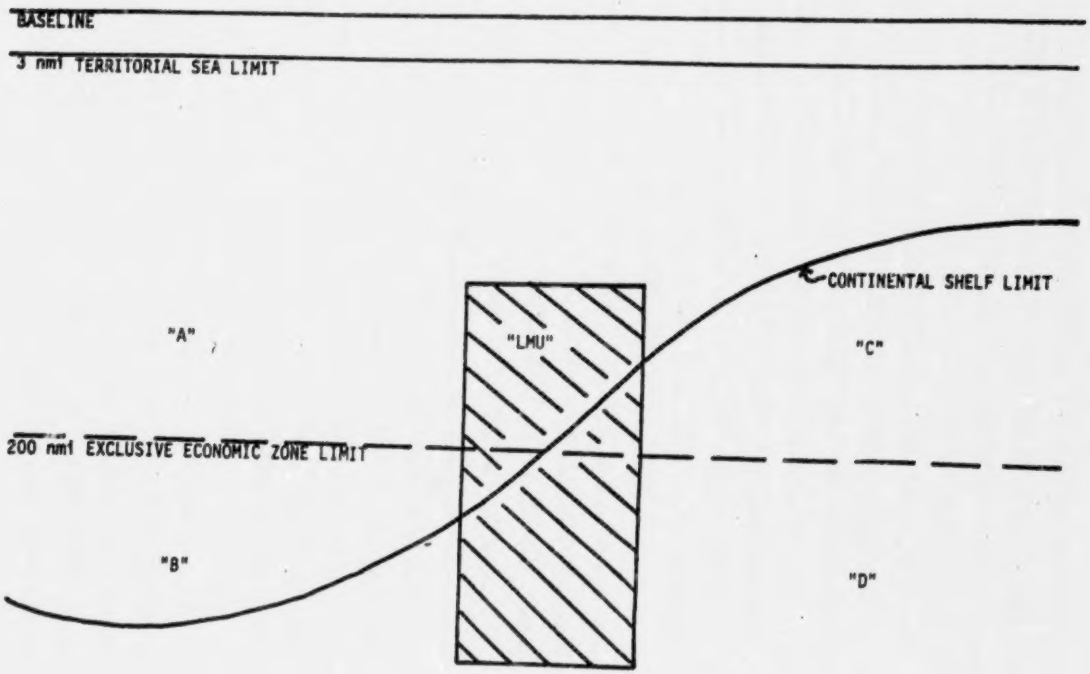
A closely related topic, and one for which an outside observer may have more room for comment than involved public officials, is the question of agency responsibilities in marine minerals development and regulation. In recent months there seems to have been genuine and substantial improvement in both the degree and the scope of coordination and cooperation between NOAA and the Department of the Interior. The knowledgeable representatives of these agencies can give you the specifics. Nonetheless, there do seem to be some remaining overlaps or potential ambiguities within the structure of the law that go beyond the reach of good intentions and collegial teamwork. These might warrant this Committee's attention.

The jurisdictional aspects can be depicted as shown in Exhibit 14. Area "A" in this figure, located on the continental shelf and within 200 nmi of the baseline from which the territorial sea is measured, is clearly within the jurisdiction of MMS under the OCSLA for hard mineral leasing purposes. Area "D", located seaward of the continental shelf break and the 200 nmi limit, falls clearly within the jurisdiction of NOAA for "nodules" exploration licensing and commercial recovery permitting purposes. The principal areas of apparently overlapping authority, jurisdictional ambiguity, or undefined responsibility are: (1) any OCS areas (area "B") that may exist beyond the 200 nautical mile (nmi) EEZ; (2) any areas that may exist within the 200 nmi EEZ but beyond the limit of the OCS (area "C"); and (3) any "non-nodule" resources that may exist beyond both the 200 nmi EEZ and the limit of the OCS.

Although DSHMRA is specific in its application to "nodules" as a hard mineral resource, it is possible that the Act could be interpreted or amended to apply to any potential hard mineral resource seaward of the continental shelf or exclusive economic zone. See, for example, the domestic seabed

EXHIBIT 14

JURISDICTION OVER AREAS OF POTENTIAL MARINE HARD MINERAL RESOURCES


BASELINE
3 nmi TERRITORIAL SEA LIMIT
CONTINENTAL SHELF LIMIT
"A"
"LMU"
"C"
200 nmi EXCLUSIVE ECONOMIC ZONE LIMIT
"B"
"D"

mining laws of France (21 I.L.M. 808-14 [1982]), the Soviet Union (21 I.L.M. 551-53 [1982]), and the United Kingdom, Section 1(6), (20 I.L.M. 1217-27 [1981]), and the United Nations Convention on the Law of the Sea, Art. 162(2)(o)(ii), (A/CONF.62/122 [7 October 1982]).

Apart from unresolved questions of geographical jurisdiction, a real problem could someday arise in cases represented by the hatched area in Exhibit 14 labelled "LMU" (for "logical mining unit") where an area of minimum efficient size for economic exploitation of a resource spans constructed legal and geographic boundaries. Since the "LMU" area may overlap both areas "A" and "D" (as well as areas "B" and "C"), it is clear that both agencies may have jurisdiction over a portion of a potential resource.

Even if such ambiguities are satisfactorily resolved for geographical issues, they may be more difficult to unravel for the respective promotional, research and development (R&D), and support responsibilites of Commerce and Interior. However, that may not be so bad.

Actually, such ambiguities and rivalries can be expected in any situation where one agency has general management responsibility for a medium where resources are found (such as ocean space) while another agency manages a class of resources (such as hard minerals) that might be extracted from that medium. My discussions with officials in other governments, for example, suggest that similar situations have been experienced in at least France, Colombia, and the Peoples Republic of China.

Under certain conditions some jurisdictional overlap and managerial rivalry can be beneficial, both for the agencies' industrial constituency and for the quality of public policy making. Especially in the early stages of an evolving legal regime, private interests who are contemplating investment in resource development may find enhanced access and greater scope to influence agency decisions when more than one agency is centrally involved in the process. Similar benefits also may be enjoyed by other involved interests, such as environmental organizations. Simply put, these are some advantages of competition over the "monopoly" of single agency management.

Where the allocation of public funds and the selection of research agendas depend critically, as they do for marine hard minerals, on scant scientific knowledge, it is especially important that public decisionmakers have both accurate scientific information and balanced appreciation of its significance. One reasonable organizational response to this problem is diversification of information sources and decentralization of discretionary decisionmaking. A competitive system of checks and balances can thereby be attained through interagency overlap and rivalry. Interagency competition for responsibilities thus may be beneficial by increasing accountability.

Multiple agency management responsibility can also enhance flexibility in the face of uncertainty and can provide increased scope for coordinated combination of different agency strengths and specialties for work with which both are familiar. The scale and timing of marine minerals resource development is surrounded by uncertainty. A complex, and still poorly defined, variety of functions will be necessary to convert this resource potential into a flow of economic supplies. Premature monopolization of all these functions by a single agency could sacrifice the benefits of multiple agency management at a time when they seem most essential. With proper planning and study, it should be possible to achieve these benefits with a minimum of the adverse effects of multiple-agency management.

That concludes my statement, Madam Chairwoman and Members of the Committee. Thank you for the opportunity to testify on this topic of national interest, and thank you for your patient attention. I will be pleased to provide the Committee with any additional information you may seek on the points I have discussed.

Ms. **Mikulski**. Thank you very much, Mr. Broadus. Before moving on to Mr. Myron Nordquist, an attorney with extensive experience in this area, the chair would like to note that Mr. McKernan had been here, from Maine, and welcomes the gentlelady from Rhode Island, Ms. Schneider, who will also be participating in the hearing.

Mr. Nordquist?

Mr. **Nordquist**. Thank you, Madam Chairwoman.

STATEMENT OF MYRON NORDQUIST, ATTORNEY

Mr. **Nordquist**. As you indicated, I'm an attorney that has concentrated on ocean resources law. I represent several clients that are interested in the exploration and development of the minerals that are within the domestic jurisdiction of the United States, and in particular, one consortium that is looking at the commercial viability of the cobalt deposits within the 200-mile zone of Johnston Island.

I have submitted a statement that gives a number of detailed and specific comments on proposed legal and regulatory issues, and would appreciate it if that could be put into the record.

Ms. **Mikulski**. I'm sorry, I missed that point.

Mr. **Nordquist**. I was asking if my written statement could be put into the record.

Ms. **Mikulski**. So ordered.

Mr. **Nordquist**. Thank you. I have two points to make which more or less harmonize with the chorus that you're getting from this hearing this morning. They relate to scientific information and the statutory, regulatory regime.

With respect to the EEZ, the President was able to almost double the resource jurisdiction of the United States with respect to hard minerals by a stroke of a pen. If we were to work out appropriate arrangements with the trust territories, the resource jurisdiction of the United States could be doubled again.

The point is, if you consider the area that's been added to the United States in the last several years for purposes of resource jurisdiction potential, it's staggering. It's quite obvious that we've now claimed it, and we don't know what we have.

Johnston Island may be an instructive example. It's a tiny little plot of ground in the mid-Pacific that has a 200-mile zone around it now that is larger than the State of California. A study that's been underway among our international consortium for a year has us very excited about the cobalt crusts that have been discovered. But the problem is that the nature of the equipment that is used to find deposits tends to be rather microscopic. We've been able to identify certain lucky strikes here and there that have excited a lot of industry interest, but what is really needed is a systematic survey that would give us the kind of general overview and topographic mapping similar to what satellite photography is giving us on land.

With an overall context, we could be much more intelligent about the use of our resources. So, the first point is that scientific data, in a general sense, on the mineral resources within the new domestic hard minerals jurisdiction of the United States is desperately needed. It is that kind of oceanographic research support that I would hope this subcommittee would consider very carefully.

My second point relates to the legal regime. The Outer Continental Shelf Lands Act does not even apply to the area off Johnston Island. The reason is very simple. The Outer Continental Shelf Lands Act, in its definitional provisions, reads in the Submerged Land Act, which, in turn, only refers to States of the Union. In other words, overseas territories and possessions, not having the status of States of the Union, are not even covered by the Outer Continental Shelf Lands Act. As things stand today, we would have no place to go to get a lease for the cobalt crusts off Johnston Island.

Now, that may be just as well because it's our view that the Outer Continental Shelf Lands Act is the wrong vehicle for hard minerals mining. It was a regime, as this committee knows very well, that was developed for oil and gas. There is enough differences among the various kinds of mineral regimes that we have to cope with to govern the deposits, that to hook our little wagon on the back of the charging train of the Outer Continental Shelf Lands Act would be a tragic mistake.

We suggest that there are elements in the Deep Seabed Hard Minerals Resources Act that could be applied to domestic jurisdiction, which is different fundamentally in that it's a territorial type of jurisdiction as distinguished from the personal jurisdiction that is used for the Deep Seabed Hard Minerals Resources Act because it is beyond national jurisdiction by definition. But it certainly is a regime that was developed for hard minerals mining in the deep water offshore.

The experience that the committee has had with that act, and the number of years that it took to get it in place, suggests that it would be very prudent to start now to develop an act that would deal with the minerals in our EEZ and continental margin beyond 200 miles.

So, my second point is simply that new legislation tailored to the domestic deep seabed mining industry is needed. Let's avoid the mistake that was made with respect to the U.N. convention on the Law of the Sea, where a half a billion dollars was spent on trying to find and develop resources and technology, only to discover that there were fatal flaws in the title that investors would get.

Let's get a good regime. The minerals out there are important. They are going to become more important if developments continue in Africa as they have. I think it's the responsibility of this committee, and I would hope that they would think it's their responsibility, to a little more foresighted than we were with our law of the sea experiences. And I can assure you that our industry group would be very eager to work with you and your staff.

Thank you.

Ms. Mikulski. Thank you for a very thorough critique of the current legislative and regulatory framework. Mr. Curtis, from the Oceanic Society?

[Statement of Mr. Nordquist follows:]

STATEMENT OF MYRON H. NORDQUIST, KELLEY DRYE & WARREN

Madam Chairwoman, thank you for the opportunity to testify before your Subcommittee during this oversight hearing on ocean mineral resources. I am a partner in the Washington, D.C. office of the law firm of Kelley Drye & Warren. My particular experience is in ocean resource law and Kelley Drye & Warren represents several commercial entities interested in both exploring and exploiting hard mineral resources in the U.S. Exclusive Economic Zone ("EEZ"). Your Subcommittee has requested me to testify in a personal capacity on the level of industry interest and activity in the development of ocean mineral resources, the technology necessary to develop such resources, economic constraints on ocean mineral exploration and development, an appropriate regulatory regime and related matters.

Because I concentrate on the international and domestic ocean law issues, my expertise on the technology and economics of deep seabed mining is limited. Accordingly, the principal focus of this testimony will be on legal and regulatory matters.

As the members know, the Deep Seabed Hard Minerals Resource Act is the domestic law that regulates the exploration for and commercial recovery of hard minerals resources in areas beyond national jurisdiction by United States citizens. Some international recognition is given to the Act through treaties among eight reciprocating states that agree to respect one another's mine site claims. This "mini treaty" system offers an alternative legal regime for mining the ocean floor from that provided in the 1982 Convention on the Law of the Sea. The Convention has been signed by one hundred fifty-nine nations but not by the United States and several other major industrial powers.

The point is that neither the reciprocating state nor the 1982 Convention regimes have given confidence to investors who are easily put off by clouds on title to resources or perceived political risk uncertainties. Mine site rights, conferred under the reciprocating states agreements, are subject to challenge by non-reciprocating states, who vastly outnumber the eight parties to the "mini treaty" regime. At the same time, many private mining companies openly distrust the International Sea-Bed Authority and the numerous novel features of the 1982 Convention set up under the United Nations.

Technological and economic problems aside, the legal regime for hard minerals mining beyond national jurisdiction is seen by many in the hard minerals industry as having fatal flaws. However valid the reasons, the fact is that very little private sector money is being spent world-wide to commercialize minerals in the international seabed area. Where financial outlays are being made, the driving force is not profit but government support for research and development of critically needed minerals or technology.

In the past several years, industry attention has increasingly shifted from the international to the domestic seabed area. The confirmation of coastal state EEZ jurisdiction in the 1982 Convention has combined with exciting new mineral discoveries within 200 miles to refocus the interest of offshore mining companies. This interest has brought to light that most nations lack adequate domestic legal regimes for hard minerals located in deep water beyond any reasonable interpretation of Continental Shelf.

No one knows if a favorable legal regime for seabed minerals within a coastal state's EEZ or continental margin beyond 200 miles would attract private sector investment. But it is evident that no legal regime or an inadequate legal regime will deter investment. Unfortunately, the United States statutory and regulatory framework for offshore hard mineral exploration and exploitation under its territorial jurisdiction is unsuitable. New laws and regulations must be enacted and implemented before substantial investment in domestic deep water mining can be made. It is ironic that the United States has a workable regime governing mining by its citizens beyond national jurisdiction but an unsatisfactory regime govering mining within its EEZ and continental margin jurisdiction.

New hard minerals legislation is needed for domestic offshore areas that is separate and distinct from the legislation that was enacted for the oil and gas industry. Much different laws and regulations are required for deep ocean minerals than are needed for offshore oil and gas.

The Outer Continental Shelf Lands Act ("OCSLA") was initially passed in 1953 to "provide for the jurisdiction of the United States over the submerged lands of the outer Continental Shelf, and to authorize the Secretary of the Interior to lease such lands for certain purposes." Section 2 of the OCSLA defines the term "outer Continental Shelf" to mean "all submerged lands lying seaward and outside of the area of lands beneath navigable waters as defined in section 2 of the "Submerged Lands Act." Section 2 of the Submerged Lands Act, in turn, defines the phrase "lands beneath navigable waters" only in reference to States of the Union. There is no statutory reference to overseas possessions, trust territories or islands such as Johnston Island not having the status of States of the Union.

Kelley Drye & Warren advises an international consortium headed by Brown & Root International, Inc. that is studying the cobalt manganese crusts in the 200-mile EEZ area off Johnston Island in the mid-Pacific. From the consortium's point of view, the prevailing United States legal regime cannot be unsatisfactory since the OCSLA does not even apply to the seabed minerals in the Johnston Island EEZ. Thus, one of the first elements for new legislation is a clear delineation of the geographic seabed areas that are under the jurisdiction and control of the United States. In this connection, it is noteworthy that the OCSLA is also ambiguous about how far United States jurisdiction extends over the continental margin beyond the 200-mile limit.

A second important point is that the OCSLA was passed with oil, gas and sulphur leasing in mind. While deep water minerals were known to exist thirty years ago, they were of no commercial interest. Accordingly, the entire statutory, regulatory and institutional framework that has evolved in the United States is oriented around offshore petroleum, and not seabed hard minerals leasing. Ingrained in such a context is the notion that a valuable public resource is being offered for which large, up-front sums of money should be paid. However, the underlying facts with respect to offshore hard minerals are radically different from those relating to petroleum. Based upon what we know today, there are no hard mineral resources sited in deep water with any commercial value. Therefor, hard minerals miners in the United States' EEZ will require incentives to prospect and mine.

Hence, a second key element in new legislation given the status of offshore hard minerals should be fair and equitable incentives for exploration and development. In this connection, consideration should be given to the granting of preferential rights for exploitation to prospectors who expend funds in prelease prospecting activities. In addition, better means need to be found to protect proprietary data: companies that sit on the sidelines should not have access to and benefits from the same information as companies that have expended these difficult to obtain early monies. The fair market value of the resource also should be factually based and the economic formula used to define potential markets for extracted hard minerals should be realistic. Competitive bonus bids should not be expected for mineral prospects with no ascertainable market value.

United States mining companies are accustomed to dealing with the Department of Interior's Minerals Management Service, Geological Survey and Bureau of Mines. By and large, relations between the prospective deep seabed mining companies and the Department of Interior are excellent. These agencies know the mining business and are great storehouses of expertise and information. At the same time, the Deep Seabed Hard Minerals Resources Act assigns lead agency responsibility to NOAA. This Act was drafted with a pioneering seabed hard minerals industry in mind and contains many features worth incorporating into new legislation for United States domestic jurisdiction. In any event, another key feature of new legislation should be to identify a single agency in the United States Government designated to act as a clearinghouse for all authorizations needed by offshore hard mineral applicants.

Lastly, it should be emphasized that the United States possesses very limited information about the hard mineral resources in its EEZ and continental margin. We need data and topographic maps.

While the Department of Interior is engaged in a general survey program that has produced remarkable topographic maps of the Continental West Coast, specific data is totally lacking in our EEZ for almost all of the individual resources being considered. Broadly stated, data is relatively comprehensive for manganese nodule deposits, less so for the massive sulfide potential (although no economic site is known) and is meager for cobalt-rich ferro-manganese crusts. The wide variations in the quantity and quality of data necessitates that much more survey work be done and that initial regulatory regims be flexible depending upon the individual requirements of specific mineral deposits

More detailed comments on an appropriate regulatory regime are contained in an appendix to this testimony. The Appendix is keyed to a list of issues identified by the Department of Interior in its formal consideration of new regulations to govern exploration under the OCSLA for minerals other than oil, gas and sulphur. The comments in the Appendix were submitted to the Department of Interior on behalf of the EEZ hard minerals consortium mentioned earlier in this testimony.

Madam Chairwoman, thank you for allowing me to present these views on legal and regulatory aspects of ocean mineral resources. I hope your leadership in examining the issues will stimulate recognition in the Congress that the OCSLA is ill-suited as a legislative or regulatory model for seabed hard mineral leasing. Indeed, attempts to amend the OCSLA could open up collateral issues better left alone. The more prudent course would seem to be new legislation specifically designed to govern deep seabed mining within United States domestic jurisdiction.

Thank you.

APPENDIX TO MR. NORDQUIST'S TESTIMONY

(A) AREA TO BE COVERED BY A PERMIT

The area to be covered by a permit cannot be given as a fixed size given the inadequate state of knowledge about the resources. The area must be large enough to contain a commercial mine site for the exploration of the mineral deposit in question. For crusts, the lifetime of a commercial operation may be twenty to twenty-five years. The area of exploration for crusts should probably be between the size of a manganese nodule exploration permit (e.g. 150,000 square kilometers) and that needed for massive sulfide deposits, whose distribution tends to be relatively more concentrated.

In this regard, exploration permits for hard minerals should cover orders of magnitude and more surface area than those allocated for oil and gas. Since the spatial distribution and concentration of deep ocean hard minerals is still largely unknown, care should be taken not to exclude any potential exploration areas from interested miners. Until the time when reasonable, reliable and verifiable data is developed to define deep ocean hard mineral distribution and concentration, DOI should place as few limitations as possible on the area to be covered by an exploration permit. We believe it is in the public interest to maximize the potential of locating an economically valuable deep water hard mineral find.

The applicant should select the size and location of the proposed exploration area. The area should be of a size that can be explored within a ten-year exploration period, in an efficient, economical and orderly manner with due regard for conservation and protection of the environment. The resource data, other relevant physical and environmental characteristics, and the state of technology should also be considered.

Proposed exploration areas should be reviewed on a case-by-case basis taking into account the seabed topography, the likely location of mineral deposits and the nature of the planned equipment and operation. If unmineable areas are known, they need not be included in the permit area. Likewise, the area should not necessarily consist of contiguous segments.

While 150,000 square kilometers may be a reasonable order of magnitude exploration area size, DOI should have the discretion to issue a permit for a larger area based on factors such as topography, resource abundance, distribution and ore grade.

Permittees should be allowed to relinquish part or all of their exploration area under a fundamental change in circumstance. Apart from force majeure and Acts of God, a deteriorating financial status of the permittee or strong indications of an uneconomic mine site should be grounds for relinquishment.

Given prevailing conditions, applicants for exploration permits should be encouraged to ask for very large areas. In exchange for large areas, the DOI might provide a compulsory "early relinquishment." The area could be reduced by one-half after three years and by another one-half after the end of the exploration phase.

(B) TERM OF A PERMIT

The ocean mining industry is in it infancy. Exploitation might take place over the next twenty years. Exploration might not occur on any given lease area for many years even after a discovery, due to a lack of cost effective technology and hardware. Therefore, the term of the pre-lease exploration permit should be for ten years with an automatic option to the permittee to extend for five years as well as a DOI discretionary option to extend for an additional five years (if the permittee so requests) up to a maximum of twenty years.

(C) TERMS AND CONDITIONS

Terms and conditions in DOI offshore permits can be expected to relate primarily to restrictions for the conservation of natural resources, protection of the environment, and the safety of life and property at sea. In general, terms and conditions should be made flexible to accommodate a wide variety of deposits, environmental circumstances and operational situations associated with ocean mining.

Permittees must expect to pursue diligently the activities described in any prelease exploration plans required to be submitted to DOI for approval. Periodic, reasonable exploration expenditures by permittees should be required to discourage speculators. However, the DOI should take into account the size of the permittee's exploration area, specific factual constraints and other relevant factors. The main point is that the terms and conditions regarding diligence should seek a balance between encouraging responsible, and discouraging irresponsible miners.

The DOI must consider the impacts exploration activities may have on the environment. If an environmental monitoring plan is required, permittees should propose its essential parameters given the extensive legal and regulatory regime already in place. Permittees should pay due regard to the conservation of natural resources, the avoidance of waste and the future opportunities for the commercial recovery of the unrecovered balance of the hard mineral resources in the exploration area. Permittees should also expect to abide by reasonable terms and conditions relating to safety at sea on such matters as vessel design, construction, alteration, repair, equipment, operation, manning and maintenance.

(D) APPLICATION REQUIREMENTS

The application must contain information sufficient to demonstrate to the DOI that the applicant is reasonably capable of committing or raising sufficient resources to cover the estimated costs of the proposed exploration program. Information on financial resources may include a description of how the applicant intends to finance the exploration program, the estimated costs of the exploration program, and the credit rating of the applicant. The application should also contain information sufficient to demonstrate to the DOI that the applicant has the technological capability to carry out the exploration program set out in the applicant's exploration plan. In particular, the applicant should demonstrate sufficient knowledge and skill to utilize the exploration equipment described in his application for the exploration program. In addition, applicants should be capable of undertaking the environmental monitoring required by United States law. Applicants should cite any relevant experience which they have in using either exploration or environmental monitoring equipment.

Each application should include an exploration plan describing the applicant's projected exploration activities expected to be undertaken during the initial ten-year preexploration permit. The plan should indicate that the applicant has the ability to apply for and obtain permits for leasing and commercial recovery. The exploration plan should cover the activities proposed to be carried out during the period of the permit, describe the areas to be explored as well as the intended exploration schedule. In this regard, account should be taken that different applicants will have different concepts and technologies and that the scheduling should be considered an approximate projection of the exploration activities planned. Applicants should be asked to describe the methods to be used to determine the location, abundance and assay quality of the resource and to measure the physical conditions in the area which will affect the recovery system design and operations. Applicants should provide a general description of the developing recovery and processing technology related to the proposed permit and of any plan or ongoing testing and evaluation of such technology. Applicants should describe the measures they will undertake to protect the environment and to monitor the effectiveness of environmental safeguards and monitoring systems for commercial recovery. Lastly, the applicants should present an estimated schedule of expenditures related to the diligence requirements of the pre-exploration permit.

(E) APPLICATION FEES

One of the biggest concerns about the OCS Lands Act is the requirement in section 8(k) that reads as follows:

"The Secretary is authorized to grant to the qualified persons offering the highest cash bonuses on a basis of competitive bidding leases of any mineral other than oil, gas, and sulphur in any area of the outer Continental Shelf not then under lease for such mineral upon such royalty, rental, and other terms and conditions as the Secretary may prescribe at the time of offering the area for lease."

The pioneer nature of hard minerals exploration in deep waters off the United States hardly demands a system of competitive bidding for leases or the payment of up-front bonus monies to the DOI. The OCS Lands Act rules were developed for a well-defined, state-of-the-art, mature, wellfinanced, high concentration of resources, high economic yield of recovered resources, and thus fast payback or return on investment industry, namely, oil and gas. Such rules do not and should not apply to any industry that is not very similar to the offshore oil and gas industry.

In our view, there should be no application fee for offshore hard minerals given the strong national interest in encouraging exploration for strategic and critical materials under United States jurisdiction. All available funds should be devoted to the exploration effort. As a practical matter, it is not anticipated that there will be competing demands for the same exploration areas. but if that situation does arise, our group recommends that the Department of Interior grant permits to areas on the basis of the quality of the proposed exploration plan and the demonstrated financial and technological capability of the applicant.

(F) EXPLORATION PLANS

The exploration plan must be highly flexible as technical development cannot be sufficiently foreseen at this stage. In addition to the items described in paragraph "c" above, the schedule of work should indicate generally when each of the following activities are projected to occur:

1. Survey cruises to determine the location and abundance of the resources as well as the sea floor configuration, ocean current and other physical characteristics of potential commercial recovery sites;
2. Resource assays to determine metal contents;
3. Design and testing of onshore and at sea system components;
4. Design and testing of mining and processing systems which simulate commercial recovery and processing;
5. Commercial scale operations based on technical, economic, legal, political and environmental considerations; and
6. To the extent known, application for other permits needed to construct and operate commercial scale facilities.

(G) AVAILABILITY OF DATA AND INFORMATION TO MMS

Permittees should expect to keep records consistent with standard accounting principles which will disclose the expenditures for exploration of hard mineral resources in the area under permit to demonstrate compliance with diligence requirements. These records should be reasonably available to pertinent authorities for verification. Other data gathered by permittees that is essential for preparing required environmental assessments or impact statements should be released with the consent of the permittee to authorized persons or institutions appointed by the DOI. In this latter instance, no data should be released until after its content has been discussed and agreed upon by the permittee. The MMS should establish a privileged or confidential data handling system for any information considered by the permittee to warrant being handled in such manner. A confidential system is particularly important for mine site data.

Requests for confidential treatment of information by permittees should state the period of time for which confidential treatment is desired. The DOI should segregate such information from non-confidential data and, wherever possible, the information should be appropriately marked as being of a confidential matter. Permittees should present reasons why the information should be kept confidential citing such matters as the commerical or financial character of the information, the nature or extent of the competitive advantage enjoyed as a result of the information, the nature and extent of the competitive harm which would result from public disclosure of information, the extent to which the information has been disseminated to employees and contractors submitting the information, the extent to which persons other than those persons submitting the information possess or have access to the same information, and the nature of the measures which have been taken to protect the information from disclosure. In all cases, the permittee should be asked to consent to the dissemination of any confidential information or data. In addition, the permittee should be given assurances by the DOI that any independent contractors or third parties will not make unauthorized disclosure of the information or data without the express consent of the permittee. Subcontractors or agents should be held liable for any authorized use or disclosure of the information or data to third parties.

(H) AVAILABILITY OF DATA AND INFORMATION TO THE PUBLIC

No information should be available to the public which is considered by the permittee to be protected by the Trade Secrets Act (18 U.S.C. 1905) or otherwise to be a trade secret or commercial or financial information which is privileged or confidential. Permittees should have procedures available that are not unduly-burdensome to substantiate for DOI that there is a proper basis in the law of withholding identified information.

(I) APPROPRIATE ROLE OF ADJACENT STATES

As the focus of this group is on the crusts within the 200-mile Exclusive Economic Zone of Johnston Island, there is no impacted adjacent State. However, where adjacent coastal States are impacted, there should be early and extensive informal consultations not only between governmental entities but also between industry and local governments.

(J) PUBLIC PARTICIPATION

We support the statutory and regulatory requirements already in place providing for public participation and believe that these requirements are sufficient. Moreover, it is noted that DOI has already exceeded any local obligation for public participation by creating joint Federal-State task forces. One is with the State of Hawaii whose mandate includes the 200-mile area off Johnston Island. A second is with the States of Oregon and California for the proposed Gorda Ridge lease area.

(K) LIMITATIONS ON EXPLORATION ACTIVITIES

As noted under paragraph "c" above, permittees should be allowed to prepare for and carry out mining operations, including the removal of resource samples large enough for subsequent processing studies. To the extent that the individual characteristics of the resource or surrounding environment require, the permittees should be given the flexibility to undertake whatever activities are necessary to achieve the goals of the pre-lease exploration plan and program. Again, the main idea is that no one knows precisely what to expect and a flexible approach is necessary given the inadequate information and data available.

(L) ENVIRONMENTAL CONSIDERATIONS

There are ample laws and regulations in existence to ensure protection of the marine environment from the effects of exploration activities. The DOI would not issue a permit if the exploration proposed in an application could reasonably be expected to result in a significant adverse effect on the quality of the environment. The terms, conditions, and restrictions in the permit will require the acquisition of relevant data and other information needed to assess the environmental impacts. Again, flexibility with respect to constraints is required to give the permittee the ability to develop and evaluate possible methods of mitigating any adverse environmental effects.

(M) DRILLING, CORING, AND SAMPLING ACTIVITIES

Permittees should be authorized by the DOI to conduct appropriate drilling, coring, and sampling activities. In addition, dredging and small scale mining operations must be anticipated. Decisions on such matters should be made on a case-by-case basis in light of the highly individualized requirements of each permit. An elaborate set of constraints should not be required.

(N) INSPECTION AND OBSERVATION OF EXPLORATION ACTIVITIES

Permittees holding pre-exploration authorization permits from the DOI must allow reasonable access by Federal government officials to inspect and observe activities required to discharge their legal responsibilities. Such officials should be accommodated by permittees to report on the effectiveness of the terms, conditions, and restrictions of the permit and whether compliance is being made with the regulations and the term, conditions, and restrictions of an individual permit. For certain activities, Federal inspectors or observers will be required to monitor environmental and other effects of the permittee's activities under the permit. When on board a permittee's vessel, such officials should be allowed access to communication equipment and navigation equipment essential for their duties. However, if potential proprietary or confidential information is recorded, permittees should be allowed an opportunity to review all aspects of reports and to request confidential treatment where appropriate. In the event that proprietary or confidential information becomes relevant to a judicial proceeding, the DOI should be required, consistent with due process, to move to have the record sealed under applicable provisions of law.

(O) SUPERVISION OR CANCELLATION OF PERMITS

Permits should be supervised to the extent necessary for compliance with applicable laws and regulations. However, permits should not be suspended or revoked unless the permittee substantially fails to comply with any provisions of United States law or any essential term, condition or restriction of the permit. Even in such cases, the permittee should be afforded all of the due process protections provided by the United States Constitution and the procedural safeguards embodied in statutes such as the Administrative Procedures Act.

(P) VIOLATION OF PERMIT TERMS AND ENFORCEMENT OF REQUIREMENTS; AND (Q) PENALTIES AND APPEALS

Permittees should not be exposed to criminal penalties or threatened with heavy fines or prison for alleged breaches of pre-lease exploration regulations. Permittees should be informed of the basis for any contemplated violation and given an opportunity to correct the deficiency, if at all possible. A reasonable period of time should be allowed to the permittee for the correction of minor violations. For more serious violations, an administrative review should be allowed to proceed concurrently with efforts to correct the deficiency. Any final determination by the DOI must be subject to judicial review as provided in Chapter 7 of Title 5, U.S.C. The issuance of any notice of probable violation should not affect the continuation of exploration activities by a permittee absent the most extraordinary of circumstances.

STATEMENT OF CLIFTON CURTIS, PRESIDENT, OCEANIC SOCIETY

Mr. CURTIS. Thank you, Madam Chairwoman. The Oceanic Society appreciates your invitation to present testimony today. I request that our written statement be incorporated into this hearing record.

Despite the important discoveries and advances of recent years, with deep ocean mining—as others today have indicated—we are still at the very front end of the development of a new technology. As we move forward with the development of regulatory regimes, therefore, caution is in order while seeking the necessary answers to important scientific and technological questions.

As shown by several examples in my prepared statement, in its broad design the act sets out a comprehensive framework for environmental protection. With the benefit of 5 years of experience since the passage of the act, however, the society believes that amendments are needed in five areas to more clearly delineate future research and regulatory needs.

The first area concerns baseline information. Under the act, NOAA is authorized to require applicants for commercial recovery permits to submit environmental baseline information as part of the application. Such information will be invaluable to NOAA in preparing site-specific EIS's and in determining the need for permit-specific terms. It is unlikely, however, that the proposed permit regulations will require applicants to submit this information. We therefore would suggest that the act be modified to mandate its inclusion.

Our second area of concern involves monitoring. The act is very clear in requiring monitoring for all license and permit phase activities. Environmental monitoring is essential to assess properly the impacts of deep seabed mining on the ocean. Unfortunately, NOAA's exploration regulations do not require companies to conduct monitoring unless they engage in at-sea mining tests.

We believe that some specified level of effort is needed to provide evolving information on deep ocean processes and the benthic community during all phases of both exploration and commercial recovery activities. For this reason, we urge this subcommittee to reaffirm the act's monitoring requirements.

Our third concern addresses scope of coverage. Under the act, NOAA has jurisdiction over mining of manganese nodules on the deep seabed beyond the limits of national jurisdiction. In other forums, the Oceanic Society has expressed its views on the inadequacy of existing statutory to regulate deep seabed mining within our Nation's EEZ. We concur in the statements just presented by Myron Nordquist.

We believe that the Deep Seabed Hard Mineral Resources Act should govern throughout the deep ocean, including the EEZ, absent substantial revisions to the OCSLA. The act sets forth an environmental framework far superior to the OCSLA.

Assuming a dual statutory approach is retained, with the OCSLA appropriately amended—or new legislation enacted—then the Act still should be amended to provide for comprehensive coverage byond 200 miles of our coast.

Our fourth concern addresses domestic research activities. Basic scientific information is lacking with respect to the characteristics of deep seabed areas, resource assessments, and the environmental impacts of proposed mining activities. Gathering necessary scientific data is the important task at hand.

In order to focus appropriate attention on this task, the Oceanic Society believes the act should be amended to mandate the development and implementation of a coordinated long term research strategy in relation to deep seabed mining throughout the deep ocean, including the EEZ. We also recommend that the act be amended to condition the issuance of commercial recovery regulations upon completion of such studies, or upon an interim report. And we also believe that similar conditions should be applied to EEZ activities.

Our fifth concern involves international activities. The act endorses the need for cooperative initiatives at the international level. Nonetheless, there are two matters involving mining systems tests and stable reference areas where further guidance is needed. For both we encourage this subcommittee to develop appropriate language to encourage the Department of State and NOAA to actively pursue bilateral or multilateral agreements that will address the concerns presented in my prepared statement.

Madam Chairwoman, I would be happy to answer questions that you or other members might have. With a cooperative spirit among all interested parties, we believe that the act can be reauthorized in a mutually acceptable manner. We look forward to working with you in this effort.

Thank you.

Ms. MIKULSKI. Thank you very much.

[Statement of Mr. Curtis follows:]

STATEMENT OF CLIFTON E. CURTIS ON BEHALF OF THE OCEANIC SOCIETY

I am Clifton Curtis, the President of the Oceanic Society, a national non-profit environmental membership organization dedicated to the protection, conservation and wise use of marine and coastal resources. The Society appreciates your Subcommittee's invitation to present testimony today in relation to the reauthorization of the Deep Seabed Hard Mineral Resources Act. Our organization, along with others in the environmental commuunity, has a long history of active involvement in efforts to ensure that any international or domestic regimes for deep seabed mining be developed in an environmentally sound manner.

I. INTRODUCTION

The oceans, covering more than 70 percent of the earth's surface, play a critical role in maintaining a livable environment. Our natural deep-sea and near-shore marine systems existed for millions of years before the appearance of humans. Until very recently, protection of the marine environment has been achieved by default, because the deep sea was too remote to be affected greatly by human activity. We all agree that human activities can have a profound adverse impact on the marine environment and its resources. Pollution from tankers and offshore oil and gas deposits, land-based contamination of near-shore areas, and the dumping of wastes in the ocean have denigrated the marine envirnment.

Despite the important discoveries and advances of recent years, with deep ocean mining we are still at the very front end of the development of a new technology. Our intervention by exploitation, and even by vigorous exploration, of manganese nodules, cobalt crusts polymetallic sulfides will disrupt the marine environment. As with other human activities that interest with deep-sea and coastal systems, decisions to proceed with deep seabed mining must be accompanied by actions that will minimize the environmental risks and provide for the suspension of operations where unacceptable harm appears.

How concerned need we be with the environmental impacts associated with deep seabed mining? As present, scientific understanding of deep-sea systems and processes is very limited, as is our knowledge concerning the possible environmental impacts of deep seabed mining. Pertinent research has been funded by the National Oceanic and Atmospheric Administration (NOAA) since the mid-1970s. That research, along with other research sponsored by federal agencies, the academic sector and industry, has advanced significantly our understanding. But much more is needed. At this time no one really knows the environmental consequences of deep-sea mining.[1] As we move forward with the development of regulatory regimes, therefore, caution is in order while seeking the necessary answers.

While portions of the Deep Seabed Hard Mineral Resources Act's "Findings and Purposes" are inconsistent with the United States' regrettable decision not to sign and seek ratification of the law of the Sea Convention, Section 21(b)(4) provides the backdrop to the Oceanic Society as comments today, i.e., that an important purpose of the Act is: "to accelerate the program of environmental assessment of exploration and commercial recovery of hard mineral resources of the deep seabed and assure that such exploration and recovery activities are conducted in a manner that will encourage the conservation of such resources (and) protect the quality of the environment. . . ."

In its broad design, the Act sets out a comprehensive framework for environmental protection. The Act's provisions contain several noteworthy examples of appropriate environmental safeguards, including:

Before NOAA may issue any license or permit, it must prepare a programmatic and site-specific Environmental Impact Statements (EISs) pursuant to the National Environmental Policy Act (NEPA) of 1969 (Sec. 109(c) (d)).

Before issuing a license or permit, NOAA must find that the exploration or commercial recovery proposed in an application cannot reasonably be expected to result in a significant adverse effect on the quality of the environment (Sec. 105(a)(4)).

Each license or permit issued by NOAA must contain terms, conditions and restrictions (TCRs) which prescribe the actions of the licensee or permittee must take to assure the protection of the environment (Sec. 109(b)); and NOAA must modify those TCRs if relevant data and other information indicates that modification is necessary to protect the quality of the environment (Sec. 105 (c)(1)(B)).

Licensees and permittees must monitor the environmental effects of their activities in accordance with guidelines issued by NOAA, submitting such information as NOAA finds to be necessary and appropriate to assess environmental impacts and to develop and evaluate possible methods of mitigating adverse environmental effects (Sec. 114).

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[1] See, e.g., Comments of the Oceanic Society and twenty-five other environmental and citizen organizations, as submitted to NOAA in response to its four Deep Seabed Mining Exploration License Draft Environmental Impact Statements, July 13, 1984.

The use of best available technologies is required to mitigate significant effects on safety, health and the environment, except where incremental costs are determined by NOAA to outweigh incremental benefits from use of such technology (Sec. 109(b)).

The Secretary of State and the Administrator of NOAA, in cooperation with other nations, must establish "stable reference areas" (SRAs) where no mining of the seabed will occur (Sec. 109 (f)).

Since passage of the Act in 1980, NOAA has promulgated regulations for exploration licenses, approved four such licenses in 1984, and is in the final stages of issuing draft regulations for the commercial recovery permits. The Oceanic Society's participation in NOAA's regulatory implementation process—and our parallel participation over the past two years in the Department of Interior's Minerals Management Service efforts to create a statutory basis and develop a regulatory regime for deep seabed mining within the Exclusive Economic Zone—provides the context today for suggesting several amendments to the Deep Seabed Hard Mineral Resources Act. Those amendments, which carry forward the letter and spirit of the Act, would more clearly delineate future research and regulatory needs.

II. SPECIFIC CONCERNS

A. Baseline information

Under Section 103(a)(2) of the Act, NOAA is authorized to require applicants for commercial recovery permits to submit environmental information on the proposed minesite as part of a permit application. Baseline information characterizing marine environmental conditions in the site will be invaluable to NOAA in preparing site-specific EISs and in determining the need for permit-specific TCRs.

It is unlikely, however, that the proposed permit regulations will require industry to compile baseline information for inclusion in the permit applications. We therefore would suggest that the discretionary language in Section 103(a)(2)(C)—"as is appropriate and necessary"—be modified to mandate the inclusion of such information.

While specific baseline informational requirements are best addressed in the regulations, it also would be helpful for the hearing report accompanying Congress' reauthorization of the Act to indicate the types of information that would be appropriate. At minimum, permit application information should include data generated continuously over several years. Such data should be sufficient for comparison with site-related information from NOAA's Deep Ocean Mining Environmental Study (DOMES) program; it should identify specific conditions that may merit permit-specific TCRs' and it should provide an adequate basis for impact assessments in conjunction with the monitoring studies discussed below.

There is ample time remaining during the ten-year exploration license periods for industry to perform this task. Given the proximity of the four license sites in the area between the Clarion-Clipperton fracture zones, cooperative industry cruises could be scheduled to gather the necessary baseline information for any permit applications.

B. Monitoring

The Act requires monitoring for all license and permit phase activities. Section 114 is unambiguous in stating that: "Each license and permit issued under this title *shall require* the licensee or permittee . . . to monitor the environmental effects of exploration and commercial recovery activities in accordance with guidelines issued by the Administrator."

Environmental monitoring is essential to assess properly the impacts of deep seabed mining on the ocean. Even though NOAA's research to date reveals no significant adverse impacts associated with license phase activities, those findings are preliminary and the Act clearly requires monitoring as an ongoing activity.

Unfortunately, NOAA's regulations for exploration licenses do not require companies to conduct monitoring unless they engage in at-sea mining tests. While pre-systems test activities should not require extensive monitoring, some specified level of effort by the licensee would provide envolving information on deep ocean processes and the benthic community, and thereby enhance the prospects of effective monitoring during commercial recovery phases when such data becomes even more crucial. With respect to the commercial recovery regulations, monitoring similarly must be included as part of the TCRs for all phases of the permit.

Given the mandatory language contained in Section 114(3), the Oceanic Society urges this Subcommittee to reaffirm the Act's monitoring requirements—either by amending Sections 103(2) (B) and (C) to reference that mandate, or by receiving assurances from NOAA officials that license phase TCRs will be revised and that commercial phase TCRs will incorporate that requirement.

C. Scope of Coverage

Under the Act, NOAA has jurisdiction over mining of manganese nodules on the deep seabed beyond the limits of national jurisdiction. Given the "hard mineral" definition contained in Section 4(6), there is a question of whether polymetallic sulfides are included within the scope of the Act. More importantly, the President's March 10, 1983, Exclusive Economic Zone Proclamation establishing national resource jurisdiction over minerals out to 200 miles would appear to restrict NOAA's geographic jurisdiction to areas beyond 200 miles of the United States' coastline.

In other forums, the Oceanic Society has expressed its views on the adequacy of other statutory authority to regulate deep seabed mining within our Nation's EEZ. Summarily stated, we believe that statutory authority remains unclear as to which Federal agency does or should have regulatory responsibility for EEZ hard rock mineral mining. Assuming the Department of Interior is correct in its assertion that the Outer Continental Shelf Lands Act, as amended, does apply, with the Minerals Management Service shouldering the regulatory responsibilities, that statute is totally inadequate as now written.

From a broader perspective, we think the development of a cohesive and coherent oceans policy militates against fragmentation of jurisdiction over hard rock minerals in the deep ocean. Federal authority over the development of mining regimes should not depend upon whether the deposit lies on or off the continental shelf, or upon whether that deposit is found 201 miles from our coastline, rather than 200 miles. Given the prospect of recoverable deposits at the Juan de Fuca ridge, which bridges the seaward edge of our EEZ, does it really make sense to have two very different laws governing the potential development of those minerals?

It is the Oceanic Society's view that the Deep Seabed Hard Mineral Resources Act should govern throughout the deep ocean, absent substantial revisions to the OCSLA. As shown by the examples of noteworthy environmental safeguards in the Introduction, above, the Act sets forth an environmental framework that is far superior to the OCSLA's. Moreover, through its manganese nodule-related research dating back to the early 1970s, and regulatory implementation activities since the passage of the Act, NOAA has developed the expertise that is needed. Hard rock minerals on the ocean floor exhibit a commonality of resource' which, from an environmental and regulatory perspective, is what counts. In additon, NOAA's general responsibility within the federal government for developing an overall oceans policy provides the most appropriate framework for addressing this special new use of our oceans.

Assuming that the dual statutory approach is retained, with the OCSLA appropriately amended, the Deep Seabed Hard Mineral Resources Act still should be amended to provide for comprehensive coverage of all forms of mineral deposits beyond 200 miles of our coasts. That objective can be readily accomplished by striking the words "of nodules" from Section 4(6)'s definition of a hard mineral resource.

D. Domestic Research Activities

As alluded to in the Introduction, above basic scientific information is lacking with respect to the characteristics of deep seabed areas, resource assessments and the environmental impacts of proposed mining activities, with impact assessments being extremely speculative given our limited knowledge of the types of technologies that might be employed. This is equally true for areas within and beyond our Nation's EEZ. As is well documented in numerous other forums, given the current and projected near-term depressed status of metals markets there is no need to rush forward with further development of regulatory mechanisms for deep seabed mining at this time. gathering necessary scientific data is the important task at hand.

In order to focus appropriate attention on gathering basic scientific information, the Oceanic Society believes it would be appropriate for the Act to be amended to mandate the development and implementation of a coordinated long-term research strategy in relation to deep seabed mining throughout the deep ocean, including the EEZ. Such a strategy would benefit from and build on NOAA's earlier Deep Ocean Mining Environmental Study, and on its more recent five-year research plan that was developed in 1981.[2] Studies such as those suggested in EEZ-related legislation (H.R. 2048) introduced earlier this Session by a member of your full Committee, Rep Bosco, could be addressed as part of such a strategy. Baseline information data and monitoring studies, as discussed above, also would be important components.

Given the importance of ths research task, we also would recommend that the Act be amended to condition the issuance of commercial recovery regulations upon completion of such studies, or upon an interim report meeting certain benchmark objectives. Such an approach is entirely consistent with NOAA's earlier "Projected Industry-Government Schedule" that linked its promulgation of commercial recovery regulations to the receipt of important research data.[3] By implication, any regulatory initiatives directed towards hard rock mineral leasing within our EEZ similarly should be tied to the research strategy.

E. Coordinated international activities

While the United States has decided to pursue its deep seabed mining interests outside of the Law of the Sea Convention, which offers the most appropriate framework for coordinated marine-related research and other activities, the Act nonetheless endorses the need for cooperative initiatives at the international level. As one example, Section 118(f) mandates that NOAA "shall provide [reciprocating states] with information on environmental impacts of exploration and commercial recovery activities, and shall provide any technical assistance requested in designing regulatory measures to protect the environment."

At the time of passage of the Act, Congress expected that mining systems tests would occur under exploration licenses. Section 103(a)(2)(B), for example, states that any exploration plan for a license should set forth "the development and testing of systems for commercial recovery to take place under the terms of the license." Based on the license applications and subsequent representations made by the four licensees, however, it is unlikely that any systems tests will occur during the license phase. Rather, such tests will occur in the initial stages of commercial recovery.

Data from mining systems tests is essential to the development of adequate commercial recovery regulations, since it provides that most realistic basis for environmental impact assessments, and for developing appropriate mitigation measures. In the absence of such tests, any commercial recovery regulations and TCRs must, by necessity, place permittees on notice as to their very preliminary, tentative nature.

It is our understanding that Japan is planning to conduct a full systems test of prototype deep seabed mining technology in 1989 as the culmination of a nine-year national program. France and the Federal Republic of Germany may also undertake certain mining systems tests in the late 1980s or early 1990s.

We encourage this Subcommittee to develop appropriate language for inclusion in the Act to encourage the Department of State and NOAA to actively pursue bilateral or multilateral agreements with other nations that will allow for effective United States' participation in such mining systems tests, wherever they may occur. Such agreements could reference the availability of United States' baseline, monitoring and other research data, as discussed earlier, as part of such a cooperative program.

As mentioned in the Introduction, stable reference areas are an important feature of the Act. They are to be used as "a reference zone or zones for purposes of resource evaluation and environmental assessment of deep seabed mining," and they must include "the designation of appropriate zones to insure a representative and stable biota of the deep seabed" (Sec. 109(f)). The concept of SRAs is critical for the evaluation of broad benthic impacts from mining activities.[4] Designated SRAs should form part of ongoing monitoring programs, and would benefit NOAA in its efforts to promulgate effective TCRs during the commercial recovery phase.

Given the Act's prohibition on unilateral United States' action to establish SRAs (Sec. 109(f)(2)), it is essential that cooperative measures with other states be promoted and carried out in order to advance this important concept. Unfortunately, implementation of the SRA concept appears to be at a standstill. To date, the Department of State and NOAA has taken the position that it is premature to negotiate SRA designations with other states until more complete scientific information is available. Yet no research to generate such information within the United States is underway, and there are no efforts to encourage collaborative activities internationally.

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[2] U.S. Department of Commerce, NOAA, "Deep Seabed Mining Marine Environmental Research Plan 1981-85," June, 1982.

[3] Id., at 98.

[4] The findings and recommendations contained in the National Research Council's Board on Ocean Science and Policy report, "Deep Seabed Stable Reference Areas," National Academy Press (1984), provides valuable guidance in the development of the SRA concept.

In order to ensure the effective application of the SRA concept to commercial mining activities, the Oceanic Society recommends that Section 109(f) of the Act be amended to provide that no permits for commercial recovery activities can be issued absent implementation of the stable reference area concept, including SRA site designations. As with mining systems tests, DOS and NOAA officials should be encouraged to pursue bilateral or multilateral agreements to resolve outstanding scientific considerations and to adopt mutually acceptable site criteria and designation procedures. Such agreements, for example, could reference the creation of an SRA Task Force to accomplish those objectives.

III. CONCLUSION

Madam Chairwoman, I would be happy to answer questions that you or other Members of the Subcommittee might have in relation to the above comments. The Oceanic Society believes that the amendments we have proposed would strengthen the Deep Seabed Hard Mineral Resources Act, making it more responsive to current and future needs. With a cooperative spirit among members of the Congress, federal agencies, the public, private sector and research community, we believe that the Act can be reauthorized in a mutually acceptable manner. We look forward to working with you in this effort.

Ms. MIKULSKI. Mr. Nordquist, you recommend that new legislation be enacted to manage the development of hard mineral resources of the EEZ.

Would this legislation be modeled after the Deep Seabed Hard Mineral Resources Act, and what do you think are its most important features?

Mr. NORDQUIST. The model in the Deep Seabed Hard Mineral Resources Act is the best model we have. However, I don't think it is a sufficient model. If you recall, the act was interim in nature. It was directed toward manganese nodules, and its scope is limited, in fact, to a very specific kind of deposit.

The act also took on the elements of a committee putting together a camel. There could be a much tighter and a much better act drafted. This committee will have to give the elements some thought. We're dealing with a hybrid between the Deep Seabed Hard Mineral Resources Act on the one hand and the Outer Continental Shelf Lands Act on the other, which of course does govern some of the placer deposits and close to shore mining activity.

For the deep water part of hard minerals mining in the EEZ, it would be appropriate to look at the definitions of logical mining unit, the environmental planning, and the kinds of regulatory discretion that are in the Deep Seabed Hard Mineral Resources Act.

At the same time, the premises in the Outer Continental Shelf Lands Act, such as that you have very valuable resources—petroleum, in that case—and therefore, industry is going to rush out and spend a lot of money on upfront bonus biddings, and that there's going to be a lot of competition—those elements are just not realistic for offshore hard minerals.

Therefore, I think you're talking about something that's a hybrid; but if you have to start from a baseline, I suggest it be hard minerals.

Ms. MIKULSKI. Thank you very much. Mr. Curtis, you recommended several amendments to the environmental provisions of the Deep Seabed Act. Do you think these amendments are critical to protect the marine environment from the effects of ocean mining, or are they desirable?

In other words, do you think they're absolutely essential? Because you seem to have a very positive view toward the act in the way it has been working so far.

Mr. CURTIS. With the exception of one area of concern, the need for domestic research strategy, I would concede that the other recommendations are desirable at this time. I think the need for coordinated, focused research strategy is critical. That is where attention should be placed. And if that were done, if the act were amended to more clearly address that need, and to coordinate the activities under DSHMA with whatever other regulatory activities would occur, then I think at a later time the other concerns could be looked at anew in light of the research information that is gathered.

Ms. MIKULSKI. Thank you. And, Dr. Broadus, your testimony was pretty comprehensive. I don't feel I have to ask you any questions, and I'm going to yield to the gentlelady from Rhode Island to see if she has any.

Mrs. SCHNEIDER. I'd like to ask Mr. Nordquist a question. You had—I think we already have some experience in the development of oil and natural gas. And I'm curious to know if there are any particular lessons that we've learned, regulatory lessons that we've learned in that process that can be basically used for our regime that will be followed for the mining of hard minerals.

Mr. NORDQUIST. Yes, I think there are, and there's actually some evidence of that, if you will, presented this morning. I was impressed by Congressman Bosco's and by Cliff Curtis' comments. Interior and NOAA have been cooperating very well. They have formulated a task force for Hawaii and with a group for the Oregon and California coasts.

To avoid the problems that you have when you don't consult with the environmental community or with local governmental entities—they're taking the right steps. And I give credit to both NOAA and Interior for doing that.

Sophisticated people in industry now understand that they never win environmental or local goverment involvement battles. I hope they understand that.

Mrs. SCHNEIDER. Good. It would save all of us a lot of money.

Mr. NORDQUIST. Indeed, ma'am.

Mrs. SCHNEIDER. And time. Well, are there any specific ways that the mining of hard minerals ought to be treated differently than we are doing with oil and natural gas?

Mr. NORDQUIST. Yes. The most important point is to find the basis from which the committee does its conceptual approach. I think that has to start from the nature of the hard minerals industry. I don't want to take a lot of the committee's time saying why the Outer Continental Shelf Lands Act is inappropriate. But if you focus on what you need in a hard minerals regime, one of the first things you need is flexibility. You're dealing not with one kind of deposit, but with probably a half dozen deposits of potential commercial interest right now, whose characteristics are very different. And there may well be another half dozen that we don't even know about yet because we've been so unsystematic in our survey of what we have.

We need an approach that for example, if you have a deposit where you need to have a small concentrated area in order to have a viable unit, your regime would allow that. Or, if you need noncontiguous units in order to have a viable economic unit, the regime would allow that. But to, for example, approach it like gas and oil, where they have grids that are laid out as if there was no correlation with what's underneath, those kinds of approaches don't make any sense.

Mrs. **Schneider**. OK. Mr. Curtis, you had mentioned in your testimony that you thought it was necessary for an accumulation of baseline data to be made. What kind of baseline data are you suggesting be required?

Mr. **Curtis**. Especially in the deep ocean, in the Clarion-Clipperton zone, where NOAA has done its studies in the 1970's and where industry has focused its attention, more information is needed with respect to benthic community processes and with respect to the currents in that region. Some of the mapping that's being done can contribute to that.

Additional work can piggyback on what already has been done under the NOAA DOME study. I think that, with respect to baseline information on the biological, chemical, and geologic processes in that deep ocean area, more is needed.

Mrs. **Schneider**. I would have thought, at least the things that you had mentioned, were already being done, but they're not, particularly the study of the benthic zone.

Mr. **Curtis**. Some limited research is being done, some has been done. NOAA currently has some contract studies being carried out by Oregon State University and others that are directed at limited areas of concern. But the amount of money that is committed to that at this stage is very small.

Mrs. **Schneider**. You had also mentioned that you found it regretable that we did not ratify the Law of the Sea Treaty, or sign it, rather. And I share that feeling, but I'm curious about why you believe that to be unfortunate.

Mr. **Curtis**. On earlier occasions in other hearings, including hearings before this subcommittee in 1981 and 1983, the Oceanic Society expressed the view—and I think it was shared by the environmental community broadly—that on balance the Law of the Sea Convention is in the best interests of the United States and other nations.

The deep seabed mining provisions did present some problems. However, we felt that those problem areas could have been largely corrected through the Preparatory Commission regulation writing phase. But there are other new provisions contained in the treaty—such as dispute resolution—and the United States is now faced with needing to develop bilateral and multilateral agreements to accomplish the purposes that are set forth in the Treaty.

Mrs. **Schneider**. Thank you. Thank you, Madam Chairwoman.

Ms. **Mikulski**. Thank you, Mrs. Schneider. That concludes the testimony from panel two. We would now like to turn our direction to the third panel, which will deal with the mineral resources of the EEZ. If the members of this panel would step forward.

Well, the committee would like to welcome this panel, and call upon Mr. Dallas Peck, who is the Director of the U.S. Geological

Survey. Mr. Peck, the committee welcomes you and look forward to your testimony.

Dr. PECK. Thank you, Madam Chairwoman. I am accompanied today by Mr. Jack Rigg, who is the Deputy Director of the Minerals Management Service, and by Dr. Terry Offield, who is adjusting the charts, and who is in charge of our Office of Energy and Marine Geology; energy studies both onshore and off.

Ms. MIKULSKI. We're going to take those away when we hear from Greenwald and Knecht, aren't we? I know you're there, fellas. I know you're out there. I think the sonar is telling me you're there.

Dr. PECK. I have prepared written testimony, Madam Chairwoman. If I could submit that for the record, I would like to proceed with just a brief summary of our activities.

Ms. MIKULSKI. Yes. Dr. Peck, your entire testimony will be entered into the record, and please proceed in whatever fashion you would like.

Dr. PECK. Thank you.

STATEMENT OF DALLAS PECK, DIRECTOR, U.S. GEOLOGICAL SURVEY

Dr. PECK. The Department of the Interior has three bureaus that are involved in studies of offshore resources: The Geological Survey, which is involved in exploration and research and the study of the resources; the Bureau of Mines, which is involved in research on mining technology and the metallurgical processing of the ores; and the Minerals Management Service, which is involved with leasing and the supervision of leasing on the OCS. Today I will mostly be talking about the U.S. Geological Survey Program.

The proclamation of the EEZ added an exciting new frontier, and the Geological Survey is carrying out studies of the EEZ similar to those that we have carried out for 100 years on land; that is, studies of the geologic structure, studies leading to an understanding of the processes, and studies of the resources.

This first poster shows the EEZ in blue. The continental shelf there is in dark blue. The sort of resources we are talking about include oil and gas, mostly on the continental slope and rise; the alluvial deposits or placer deposits of heavy minerals in a number of areas, including right offshore Virginia and Georgia, and offshore Alaska and the coast of Oregon; sulfide deposits along spreading ridges off the coast of Oregon and northern California, that we will talk more about later; and cobalt rich manganese crusts associated with the slopes of seamounts in the mid-Pacific.

I have with me some examples of these mineral resources of the EEZ—polymetallic sulfides along the ridge, some heavy mineral deposits of titanium minerals off the coast of Virginia.

The second poster shows an example of one of our efforts in studying the EEZ, and that is a wide scan sonar image. It is a similar view to the seafloor as you would see from radar on the space shuttle or a satellite. The resolution is about 60 meters. It shows in white the submarine volcanoes, and the volcanic ridges flanking the Gorda Ridge, and the sulfide deposits we found recently are in the slot at the southern end there.

We are producing an atlas of these. We finished the west coast last year and the Gulf of Mexico this summer. The ship is studying the Puerto Rican EEZ starting Friday. Next year we will be working off Hawaii and Alaska.

This next poster shows the spreading centers off the coast of Oregon and California. These are places where actually the floor of the ocean is moving apart. The gap in between these is filled by lava, like the lava in Hawaii, upflowing along the center. The hard metallic sulfides are formed by water circulating through those hot rocks along the rifts extracting the metals and depositing on the surface.

This is a cross section of the southern part of the Gorda Ridge showing the sediments in the valley. This is a detailed sonar map prepared by the Hawaii Institute of Geophysics. We have been working in this area cooperatively with NOAA and with the Minerals Management Service, joined by Oregon State University and the Hawaii Institute of Geophysics. Our work in doing the image mapping is carried out in cooperation with the bathymetric mapping by NOAA. We have a memorandum of understanding, and we work very closely together.

Recently we held a symposium at the Smithsonian where we, together with industry, jointly discussed the matter, and we prepared——

Ms. **Mikulski**. We have the book, thank you.

Dr. **Peck** [continuing]. A booklet summarizing our studies of the EEZ. The next poster shows the distribution and nature of the cobalt manganese crusts in the mid-Pacific islands. The yellow are the EEZ in the mid-Pacific, the red are the seamounts, which are the substrates to the cobalt rich manganese crust. These are the cross sections of the seamounts showing the distribution of these crusts from depths of 3,000 to 8,000 feet on the side of the seamounts. That is a detailed one of the crust.

The content is summarized here as a cobalt content of about 1 percent, about two or three times that of deep sea modules.

I have been talking about the Survey's program. In addition, the Department of the Interior, through the Minerals Management Service, is turning out studies leading to leasing regulations for minerals in the OCS. They formed an Office of Strategic and International Minerals in order to develop a policy to encourage exploration, development, and production of nonenergy minerals. They are focusing on the cobalt-rich manganese crust of the mid-Pacific and the polymetallic sulfides off the coast of California.

That concludes my testimony, Madam Chairwoman. I will be happy to answer any questions.

Ms. **Mikulski**. Thank you very much.

[Statement of Dr. Peck follows:]

STATEMENT OF DALLAS L. PECK, DIRECTOR, U.S. GEOLOGICAL SURVEY

Madame, Chairwoman, I am pleased to be here this morning to discuss the activities of the Geological Survey in surveying and mapping ocean mineral resources, and to inform the subcommittee about recent mineral discoveries within the Exclusive Economic Zone. With me today I have John B. Rigg, Associate Director, Offshore Minerals Management, Minerals Management Service, who can answer questions regarding MMS activities in the EEZ.

The U.S. Geological Survey was charged in 1879 with "examinations of the geological structure, mineral resources, and products of the national domain." In the 106 years since then the USGS has grown to an organization of over 12,000 people with a budget of over $600 million focused on data gathering, research, and analysis in the earth sciences of geology, hydrology, and mapping. The USGS publishes reports and maps on a continuing basis on the results of these activities. Since 1965, the USGS has carried out research and investigation programs on the geologic structure, energy and mineral resources, and geologic processes of the Outer Continental Shelf as an extension of studies on land.

The EEZ includes approximately 3 billion acres compared with 2.3 billion acres onshore and provides access to potentially vast energy and mineral resources that may occur on or below the surface of the sea floor, about which little is known. The first step in exploring the new frontier of the EEZ is to find out what has been acquired. The USGS last year began broad-scale reconnaissance mapping of the sea floor, using a one-of-a-kind wide-swath sidescan sonar device (GLORIA) owned by the British Institute of Oceanographic Sciences. Each day GLORIA can map an area the size of New Jersey, with a resolution of features as small as 60 meters. The GLORIA data is designed to show the basic setting and framework of sea floor geology and to identify features or areas of scientific and resource interest for more detailed follow-on surveys.

In 1984, in 96 days at sea, the entire West Coast EEZ from the edge of the continental shelf out to 200 nautical miles was mapped using the GLORIA system. This type of survey is the necessary first step in the characterization of the EEZ. More than 100 seamounts or undersea volcanoes not previously known were revealed. Because sulfide deposits may form where chemical interaction occurs between sea water and hot volcanic rocks of the sea floor, it is possible that some of the newly found seamounts could host mineral deposits. For the first time, submarine rivers meandering for hundreds of kilometers across the sea floor were mapped. New aspects of sea floor erosion and deposition, not previously suspected at such water depths, were seen and await study and interpretation.

The GLORIA surveys are well complemented by the new SeaBEAM bathymetric charting of the National Oceanic and Atmospheric Administration being done under a NOAA-USGS memorandum of understanding. Under agreement between the two agencies, the USGS generally concentrates on the geology and geologic processes of the sea floor and beneath, while NOAA concentrates its efforts on bathymetry and studies of the water column and processes on the sea floor. This arrangement works out very well, with good coopertion between the two organizations.

The West Coast EEZ survey provides a new view of the sea floor spreading centers of the Juan de Fuca and Gorda Ridges. These are places where the Earth's crust pulls apart in fundamental plate-tectnoic processes, and new ocean crust is formed with considerable volcanic heat. Polymetallic sulfide deposits were first found in such settings, and are now known to occur just outside the EEZ at the south end of the Juan de Fuca Ridge, and within the EEZ on the Gorda Ridge. The Juan de Fuca deposits occur around a series of vents along the axial zone of the ridge; the sulfide-rich chimneys are composed mostly of sphalerite, a mineral containing about 55% zinc, with potentially interesting amounts of trace metals like silver and cadmium. Surveys show that the vents have coalesced to form a zone perhaps up to 50 meters wide and several hundred meters long. In 1984, in a joint venture with the Canadian Geological Survey, which has developed a small sea floor drill, the USGS attempted to probe the depth of these deposits. Unfortunately, we could not obtain the desired drill cores of the sulfides, so we do not know how deep the deposits might extend. The deep submersible ALVIN has made a limited series of dives to better survey and sample the vent deposits. A major multidisciplinary team is working on the samples, and will be drawing comparisons of these deposits and similar ones on land in order to try to build a complete picture of the mineralizing processes and the settings to which they act.

In 1984, the Hawaii Institute of Geophysics produced a medium resolution map of the two spreading centers, using the SeaMARC II sidescan sonar device. In a collaborative effort this past summer, the USGS, NOAA, the Minerals Management Service, and Oregon State University explored the Gorda Ridge. A NOAA cruise discovered anomalous water chemistry suggesting plumes from mineralizing vents at the north end of Gorda Ridge. A follow-up USGS cruise was designed to survey the sea floor geology of that area to try to locate any actual vents. Vents probably do occur there, but none were found; however, geologic analogy with similar sulfide deposits on land suggested to USGS scientists that the south end of the Gorda Ridge should have optimal conditions for the occurrence of sulfide deposits. The USGS vessel sailed south, used geophysics to locate precise volcanic heat sources, dredged samples from the sea floor, and brought up the first significant samples of sulfide occurrence from within the EEZ. We have no idea yet of the real nature of the find or how much sulfide there might be, but we have plans to follow up this initial find, and to expand our limited survey of the north end of the Gorda Ridge as well. We expect that work to take place in 1986, probably in cooperation with MMS, NOAA, and OSU. Scientists from Washington or California may also be involved.

A major research voyage of the USGS ship S.P. Lee in 1983 and 1984 followed the original find of cobalt- and nickel-rich manganese crusts with examination of several seamounts in the mid-Pacific region. The crusts occur widely in a water-depth window of about 800 to 2,600 meters, and consistently contain significant amounts of the three critical metals. The cobalt samples are typically richer than the African deposits that supply most of U.S. needs. The crusts are thin, however, commonly in the range of 2 to 9 centimeters (about 1 to 4 inches), and they do not uniformly blanket the surface of a seamount. So, the overall economics are similar.

The Minerals Management Service, in cooperation with scientists from West Germany, has brought up dredge hauls of material from these crusts large enough for metallurgical process testing. These samples are rich in strategic metals which are important to the U.S. economy and National defense, including cobalt, manganese, and platinum. The MMS has recently published a report which discusses the geological and physical properties which control the crust distribution and quality. The report rates the potential for the areas sampled based on the available technical information, with the highest potential in the Marshall Islands, and lesser potential in the other areas surveyed. The Bureau of Mines is studying the metallurgical treatment of the crusts, and is planning to evaluate the mining technology needed to develop them. Specifically, research is underway to evaluate beneficiation techniques and to test candidate hydrometallurgical and pyrometallurgical separation methods. Also, long-range plans are being formulated to assess mining methods that may have application for recovering the crust materials from the ocean floor.

A lot more information is needed, first to understand better the general occurrence of these crusts in a large portion of the Pacific Ocean, then to indicate general areas where industry interest might be justified so that it could carry out the necessary detailed surveys, and lastly to develop a scientific model of how, why, and where these important potential resources occur. This work will also have considerable importance to the freely associated States in the Pacific region. In addition to the United States, the Germans, Japanese, and Russians have shown strong interest and have conducted exploration cruises in the Pacific. Although the involvement of U.S. industry in EEZ exploration has been limited thus far, the Department of the Interior is interested in developing a framework that will encourage greater industry participation and investment.

The USGS plans further cobalt-crust investigations, including participating in an academic research cruise to the Marianas EEZ in 1986, and conducting both GLORIA sonar and follow-up sample-collecting surveys around Hawaii and the EEZ farther south around Johnston Island and the Line Islands in 1987. We are also expanding the knowledge of crust occurrence relatively inexpensively by obtaining every good sample of crust we can from oceanographic institution archives, and determing their chemical composition. Maps depicting results from these efforts will be available in 1986.

The USGS has not recently expended any effort on the well-recognized manganese nodules of the deep ocean. These have been well studied before and industry already has a good appreciation of them as a potential metal resource. It appears that the cobalt-rich crusts are of more pressing concern at this time. They occur at much shallower depths than the classic nodules, they are much richer in cobalt and seem to contain more significant traces of the important element platinum, and they are likely to be no more difficult or costly to mine, though some technology development may be needed first. Most critical, unlike the nodules, the cobalt crusts occur within the American EEZ.

All of the activities and deposits or potential resources discussed to this point are in the deep ocean. Closer to shore within the EEZ are heavy-mineral placer deposits. Samples taken by the USGS and the Corps of Engineers from all along the Atlantic coast are being analysed for heavy-mineral content. This summer the USGS conducted a brief sampling cruise off Virginia and Georgia and found what looks like very promising deposits. These deposits contain more than average amounts (ranging from 3 to 10 percent) of the minerals ilmenite and zircon, and occur throughout greater thicknesses of sand than usual (thicknesses exceeding 10 feet). These are like deposits that have long been mined on land, but may in fact be of somewhat better grade and should prove relatively easy to mine offshore, assuming adequate environmental safeguards.

Over the next 4 or 5 years the USGS will be publishing a compilation map series (named the Continental Margin Map Series) that will depict individual areas of the EEZ on maps showing geology, resources, bathymetry, sea floor morphology, and other basic information. The EEZ is an enormous area to survey and investigate and it will take years to learn all the Nation needs to know about the resources of its new domain. Given the newness of the venture and the experience of the very recent and unexpected discoveries, we predict that we will find still other kinds of potential resources as we continue to explore.

So far, this discussion has been oriented toward the initial exploration of the EEZ. One of the Secretary of the Interior's first actions, however, after the proclamation of the EEZ was to approve the establishment of an Office of Strategic and International Minerals in the Minerals Management Service to develop policy and implement a program to encourage exploration, development, and production of nonenergy minerals in the EEZ by the private sector. The Solicitor of the Interior Department confirmed the Secretary's authority to lease minerals in the EEZ in an opinion issued May 30, 1985.

The Minerals Management Service is currently studying the possibility of offering leases for the exploration and development of the cobalt-rich crusts in the Hawaiian EEZ and polymetallic sulfides off the coast of Oregon and northern California. To provide for full State and public participation, two Federal/State task forces have been formed to consider the economic and environmental impacts associated with possible developming a regulatory framework for nonenergy mineral exploration and development in the EEZ.

In summary, we have learned a great deal in our surveys of the EEZ, but we have just begun to scratch the surface. We at the Geological Survey and others in the Department of the Interior hope to remain in the forefront in discovering the resources of the EEZ. Thank you again for the opportunity to inform this subcommittee about our activities in the Exclusive Economic Zone. We would be pleased to answer any quesitons you may have.

Ms. **Mikulski**. The Chair wishes to note that we've been summoned to the floor for a live recorded quorum call. We are going to stand in recess to answer that call. I ask members to return as expeditiously. Because of administrative reasons, the Chair would like to move to the conclusion of this hearing as close to 11:30 as possible. So, we'll stand in recess, come back, and then hear Mr. Knecht and Mr. Greenwald.

[Whereupon, a brief recess was taken.]

Ms. **Mikulski**. The committee is called to order. We will resume taking testimony. And now the committee would like to hear from Mr. Richard Greenwald. Before I do, Mr. Peck, I'm going to thank you for an excellent testimony and wonderful visuals. The book that you were ready to present to the committee we've seen. It is excellent. And we want to compliment you on your thoroughness and your enthusiasm.

Dr. **Peck**. Thank you.

Ms. **Mikulski**. Mr. Greenwald, we look forward to hearing from you as the secretary and general counsel of Deep Sea Ventures and Ocean Mining Associates, drawer 2, from Gloucester Point, VA.

Could you tell me what a drawer 2 is? It sounds like a Federal agency there.

Mr. **Greenwald**. It's a very nice rural setting down there, Madam Chairwoman. We sit on the banks of the York River, and our community is maybe 500 people. It's a nice place to work.

Ms. **Mikulski**. Your community is called drawer 2?

Mr. **Greenwald**. No, it's Gloucester Point, VA, right across the York River——

Ms. **Mikulski**. Well, I know where Gloucester Point is. But it says Ocean Mining Associates, drawer 2.

Mr. **Greenwald**. Oh, that's our mailing address.

Ms. **Mikulski.** Oh, because I thought if you were No. 2, why didn't my staff give me No. 1. Please proceed. We are most interested in hearing your testimony.

Mr. **Greenwald.** Madam Chairwoman, I've submitted written testimony to the subcommittee, and I'd ask that it be entered in the record. I've also got a 5-minute oral summary that I'll cut down to about a minute since you're tied up for time. Would that be all right?

Ms. **Mikulski.** Mr. Greenwald, your written testimony will be placed into the record. Mr. Tallon will be coming back to assume the responsibilities of the Chair if I must leave. Take the 5 minutes because it's very important that we get a sense of this mineral resource development in the EEZ. I had said earlier that my keen interest is working with the private sector, and we'd like to hear those views.

STATEMENT OF RICHARD J. GREENWALD, SECRETARY AND GENERAL COUNSEL, DEEPSEA VENTURES, INC., AND OCEAN MINING ASSOCIATES

Mr. **Greenwald.** My name is Richard Greenwald. I'm the secretary and general counsel of Deepsea Ventures and Ocean Mining Associates, companies whose marine hard minerals program is 23 years old.

OMA strongly supported the fine deep ocean manganese nodule related environmental work accomplished by NOAA prior to passage of the Deep Seabed Hard Mineral Resources Act, which I'll call the Seabed Act, and the subsequent and timely regulatory actions, environmental programs, and licensing activities accomplished by NOAA's Office of Ocean Minerals and Energy. NOAA's future work in deep ocean hard mineral exploration is clear and vital.

NOAA must monitor the work of its licensees and must prepare for commercial regulations and permits, the associated site-specific environmental impact statements and other findings required by the Seabed Act. NOAA must also engage other ocean mining nations in cooperative international deep ocean minerals and environmental programs.

For these reasons, we respectfully recommend reauthorization of the Seabed Act for 3 additional years in order that NOAA may plan and implement a sustained research and regulatory program supporting efficient, environmentally sound, domestic and international deep ocean mining activities.

Shifting now to EEZ hard minerals, the work is just beginning. These are not very well known or understood. Many exciting discoveries have recently been made by well planned and executed seabed mapping, environmental metals processing, and hard mineral reconnaissance programs of the U.S. Geological Survey, the Bureau of Mines, the Minerals Management Service, and NOAA's National Ocean Survey.

These programs have been unusually productive, yielding new, exciting mineral and biological discoveries, partially because of the close and highly commendable interagency cooperation which now exists between Interior and NOAA. The new hard mineral discoveries include sand and gravel, placers, manganese nodules, cobalt crusts, phosphorites, and polymetallic sulfides. A wide variety of other hard minerals phenomena will undoubtedly be discovered in the near future.

None of the recently discovered EEZ hard mineral phenomena can be classifed as domestic reserves. Not enough information has yet been accumulated to support or deny that kind of a judgment. At least several of the discoveries are sure to interest industry in the mid to long term, but most are worthy of further current study, for reasons alluded to earlier by Mr. Shumway.

To input and prepare for specific EEZ hard mineral programs, the Office of Strategic International Minerals, of the Minerals Management Service, has created and staffed two very effective working groups. These groups, the Gorda Ridge Task Force and the Hawaii Manganese/Cobalt Crust Project, have been productively engaged in early phases of policy discussion and technical program planning. It has been my recommendation that a similar group be created for the southeast coast; Virginia south to Florida.

In order for industry to supplement and eventually replace these Government programs, three conditions will have to exist; first, markets will have to improve; second, fundamental EEZ data will need to be publicly available—this is the sound information base mentioned by Mr. Bosco earlier—and third, appropriate EEZ hard minerals legislation and regulations will have to be in place.

Government EEZ programs, if carried out in a sustained and systematic manner, will produce the necessary data, which will also be of great use to the Congress and to Federal, State, local, environmental, and other public interests, and to academia, to facilitate constructive advocacy and informed, effective, policy analysis, and policy formulation.

None of this activity will be commercially productive, however, unless there is an EEZ hard minerals permitting regime in place which takes into account hard minerals facts and experience.

The Outer Continental Shelf Lands Act of 1953, which I'll call the Shelf Act, does not do that. It is an oil and gas regime. It is created for regulation of oil and gas, and fleshed out in accordance with a half-century of offshore oil and gas experience. It is not appropriate as a regulatory vehicle for an as yet unborn EEZ hard minerals industry.

The oil and gas industry has indicated that they do not encourage opening the Shelf Act to amendment. On the other hand, the Seabed Act was never intended by Congress or the hard minerals industry to apply to minerals in the EEZ.

Obviously new legislation, tailored to hard minerals facts and conditions, is the solution; perhaps based upon the Seabed Act, but specifying Interior as the agency of primary jurisdiction, with cooperation from NOAA, and supplemented by appropriate provisions related to multiple uses and multiple use conflicts, and State, local, environmental, and other public participation.

In conclusion, Madam Chairwoman, I recommend an urgent inquiry into suitable EEZ hard mineral regimes, and that this be done by early consensus building action among experts of the oil and gas industry and the hard minerals industries, environmental, and other public interest groups, and academia—with advice from

Federal, State, territorial, and local government agencies—with the mandate to submit suitable legislative recommendations to Congress.

Thank you.

Ms. MIKULSKI. Thank you very much, Mr. Greenwald. Mr. Knecht?

[Statement of Mr. Greenwald follows:]

STATEMENT OF RICHARD J. GREENWALD, SECRETARY AND GENERAL COUNSEL, DEEPSEA VENTURES, INC. AND OCEAN MINING ASSOCIATES

My name is Richard J. Greenwald, and I am Secretary and General Counsel of Deepsea Ventures, Inc. and Ocean Mining Associates, both located in Gloucester Point, Virginia. I serve as Vice Chairman (Hard Minerals) of the American Bar Association's Marine Resources Committee, Section of Natural Resources Law, and on the Underseas Mineral Resources Subcommittee of the American Mining Congress.

Ocean Mining Associates (OMA) is a Virginia partnership organized and owned in equal shares by domestic subsidiaries of United States Steel Corporation, Enti Nazionale Idrocarburi (ENI) of Italy, The Sun Company, and Union Miniere, S.A. of Belgium. Deepsea Ventures, Inc. is a Delaware corporation, a majority of whose shares are held and controlled by the same corporations and which serves as a service contractor to OMA.

The marine mining program being pursued by OMA and Deepsea was begun in 1962. The 23 years which we have devoted to development of marine hard minerals potentials have been consumed in development and testing of marine mining and processing systems, the collection and evaluation of marine science and seabed prospecting data, the location of a suitable mineral occurrence, and the calculation and study of market opportunities, capital equipment and operating costs, legal and political risk factors, and the whole range of technical, legal, and financial studies normally undertaken by mining projects in pre-production phases.

In this sense, OMA's objectives in marine mining R&D are no different than those of any other mining R&D operation, whether carried out at sea or on land in Colorado, Chile or China. These objectives are:

1. To locate and secure a mineral body and to confirm if it contains reserves of sufficient quality and quantity to provide a reasonable chance for return of investment and profit.

2. To adopt or develop equipment and know-how to be applied to the mineral body in order to produce products at a competitive cost and economic price.

3. To determine if a market will exist for such products during the production run.

4. To determine if the framework of law under which such a mining operation will exist is, or will be, sufficiently clear, predictable, and fair as to permit prudent investment in the program.

The OMA marine mining program has consumed approximately $120 million in its 23 years and has produced a large, comprehensive and well tested body of hard mineral technology and know-how applicable in and on the deep seabeds and the continental shelves and margins of the World. In recent years the OMA program has been the most active of the domestic marine mining programs and recently has engaged in the study of the hard mineral resources of the Exclusive Economic Zone (EEZ) of the U.S., its Territories and Associated Pacific Islands, and the preliminary design and development of systems directly related to their exploration and commercialization. In this regard, I have submitted for the Subcommittee's use a recent paper by Raymond Kaufman of Deepsea Ventures, Inc. which summarizes presently known technical and economic factors related to the hard mineral resources of these EEZ areas.

DEEP OCEAN MINING

The domestic deep ocean mining R&D community is represented by the four NOAA licensees (including OMA, OMI, KCON, and OMCO) and has operated on the deep seabeds since the early 1960's at an aggregate investment approaching one half billion 1985 dollars. Commercially interesting manganese nodule deposits, well beyond the 200-mile limit, have been identified and licenses for further exploration and development by NOAA under the authority of the Deep Seabed Hard Mineral Resources Act of 1980 (DSHMRA). A variety of workable deep seabed exploration and mining systems have been developed and tested at sea over the years, a healthy

best copy available

technical condition for the pioneering phase of a nascent industry. Additionally, a variety of commercial approaches have led to development and testing of diverse mineral processing systems designed to serve different perceived markets.

Environmental regulation of deep seabed R&D operations has been the responsibility of the Department of Commerce before and (with other regulatory responsibilities) since the passage of DSHMRA, which Act was worked out over a 10-year period before a dozen subcommittees in the Senate and the House of Representatives. Its legislative policy and provisions, and the regulations with which the lead agency (NOAA) implemented DSHMRA, were drafted with marine hard mineral parameters and domestic ocean policy in mind. NOA, in workshops of wide and diverse composition held during the period 1972 to present, devised and implemented guidance for industrial designs, the basis for a comprehensive and defensible programmatic environmental impact statement (PEIS), formulation of effective and efficient deep seabed regulations and environmental programs and controls, and the core of individual EIS's associated with each domestic Exploration License. Licenses were issued by NOAA in 1984.

License terms and conditions require NOAA to monitor the licensees' annual work, verify conformance with their exploration plans, and assure itself of the licensees' progress toward ability to apply for commercial permits within the term of the licenses. Should any licensee require further substantial modification of licensed activity or major at-sea tests of prototype engineering systems, NOAA will be required to process and issue associated environmental impact statements.

NOAA must prepare itself for issuance of commercial deep ocean mining permits. We understand that NOAA will soon publish an Advance Notice of Rulemaking covering initial "general" regulations relating to requirements and procedures for deep seabed hard mineral commercial permit applications. If these regulations are found to be feasible (industry has not yet seen them) then planning activities for the appropriate environmental research and commercial environmental impact statements, and for the activities necessary to support the necessary determinations required by law, will begin and proceed in parallel with work on the detailed regulations which will eventually flesh out the initial commercial regulations. Finalization and issuance of these detailed regulations can, and should, be delayed until the prerequisite experience is acquired in large-scale continuous or full-scale prototype, testing under exploration license.

We note that NOAA has engaged in correspondence between and among the U.S., U.K., FRG, Italy, Belgium, France and Japan on the subject of coordination, among the signatories of the Reciprocating States Agreement (RSA), of marine mining program information, in particular environmental research program plans and activity. Environmental activity, as a beginning step toward institutionalization of the RSA, is a timely idea which is highly ethical, responsible and defensible.

The deep ocean mining R&D industry is presently retrenching as a result of the general ill health of the world-wide mining industry, a condition having particularly severe impact on the Western, privately-financed, sector of the hard rock mining community. Current metals markets are in disarray and decline, and past history does not seem to be helpful in projecting future price and consumption trends. Costs of production, and competition from foreign subsidized operations, are increasing at a rate which is independent of market conditions. Markets for manganese, cobalt, nickel, zinc, lead and copper are particularly depressed, with constant-dollar prices frequently lower than prices at the depths of the Great Depression of the 1930's. Existing domestic land mines are closing down at an alarming rate; the recent closure of the historic Bingham Canyon copper mine in Utah serves as a dramatic example. Hard-rock mining companies are making harsh cuts in R&D in an attempt to cut costs to stay competitive—and stay in business.

In this general atmosphere of gloom and doom in the privately-financed metals industry, deep seabed marine mining R&D programs have been particularly hard-hit. Activity in all domestic consortia has been severely reduced awaiting the prospect of improved metals consumption and price patterns. The primary activity in the domestic consortia is now the refinement and documentation of past engineering work and the individual analysis and integration of license-area data recently received by each consortium as a result of equity exchanges under the terms of certain private overlap conflict settlement agreements. The next full go-ahead phases of at-sea exploration and development work are just too expensive (in the $ hundreds of millions) to garner approval and funding from management under current and projected near-term market conditions.

Healthy economies demand metals, however. Markets will improve in the mid- to late 90's or by the turn of the century. While industry-financed deep ocean mining development is in the doldrums, government-financed deep ocean mining programs are going forward with considerable energy in Japan, France, W. Germany and the Soviet Union, and perhaps India, Brazil, China and Korea. Thus, it appears that deep ocean mining R&D will advance during this period of depressed metals markets, but only in countries which pursue governmental ocean mining R&D programs. Consequently, investor-financed manganese nodule R&D programs require a temporary survival mechanism which can help preserve the value of licensed minesites and technology assets, and skills while permitting program personnel to keep abreast of current marine science and engineering developments. This brings us to the subject of our new domestic EEZ.

EEZ AFFAIRS AND OPPORTUNITIES

President Reagan's 200-Mile EEZ proclamation was a declaration of the intent of the U.S. to proceed with the efficient development and careful management of the EEZ, including the strategic and critical minerals potentials to which he made special reference. The proclamation was also an affirmation of our intent to shape domestic EEZ policy compatibly with widely accepted international concepts of EEZ jurisdictional competence, limitations, and responsibilities. In keeping with this policy, the Departments of the Interior and Commerce have engaged in energetic and unusually cooperative efforts to map the EEZ topography, to do preliminary surveys of the related geology and mineralogy, and to lay the foundations for environmental research programs in these new areas of domestic jurisdiction.

EEZ hard mineral resources are much less well kown than are deep seabed manganese nodules. Industry had done little EEZ hard mineral assessment work for reasons to be discussed later in greater detail, but pertaining mainly to uncertainties of markets and lack of an economic and predictable EEZ hard minerals legal regime. Consequently, most of the work done in identification of EEZ hard mineral potentials has been done by, or for, government.

All here should be aware of the broad range of EEZ mineral occurrences so far discovered. These include sands, gravels, pleistocene beach placers, manganese nodules and crusts, phosphorites, polymetallic sulphides, and cobalt-rich crusts. A wide variety of other hard mineral phenomena will undoubtedly be discovered in the future. None of the hard mineral phenomena so far discovered can yet be classified as commercial ore—or even resources. They have not been found to be currently economic (or uneconomic) as insufficient knowledge exists to make such determinations. Some are sure to be commercially interesting in the mid- to long-term, but all are worthy of further study, even if only to gain new knowledge about the genesis and location of hidden, but perhaps more easily mined, land deposits.

Industry has stated many times over the last 20 years that a suitable outer continental shelf hard minerals legal regime is lacking and new approaches will be needed before investors will devote capital to hard mineral exploration and development on the contential shelf (or in EEZ areas beyond the continental shelf). The Outer Continental Shelf Lands Act (OCSLA) speaks to hard minerals only in one short, inadequate, unpunctuated, and inappropriate policy paragraph:

"The Secretary is authorized to grant to the qualified persons offering the highest cash bonuses on a basis of competitive bidding leases of any mineral other than oil, gas, and sulphur in any area of the Outer Continental Shelf not then under lease for any such mineral upon such royalty, rental and other terms and conditions as the Secretary may prescribe at the time of offering the area for lease."

There exists industry/government corresponence on, and analysis of, this language dating back to the late 60's and early 70's during which time Russel G. Wayland, Chief of the Conservation Division, USGS, outlined the Interior Department's administrative dedication to defense of OCSLA as the appropriate marine hard mineral regulatory vehicle. Some of us recall various conflicting opinions on the broad applicability to hard mineral operations of competitive bidding and other oil and gas based aspects of OCSLA access provisions and economic regulations. A few are aware that the industry interests and public interest groups, has consistently advised DOI that OCSLA is an inadequate and inappropriate model for access to, regulation of, and environmental control over, hard mineral activities in the EEZ.

The American Mining Congress policy statement on the subject, issued last month in San Francisco, meets the issue squarely:

"We support enactment of hard minerals legislation prior to issuance of EEZ hard mineral regulations in order to provide a legal regime based upon hard minerals economic and technical data rather than on data related to development of oil and gas."

The literature contains *no* instance of industry support for OCSLA as the EEZ marine hard mineral regime, and mounting opposition by environmental groups for such a proposition.

In order for industry to make intelligent, informed initial investment plans and decisions regarding entry into progressive stages of EEZ hard mineral activities, the following data, the taking of which has been generally recognized as a legitimate function of government, needs to be publically available.

1. Maps of the EEZ topography.
2. General geological surveys and broad mineral reconnaissance reports.
3. Environmental baseline data.

Thus, this data is needed by:

1. Congress and Federal agencies—to make national policy determinations on oceans, coastal zone and strategic minerals policy.
2. State, local and Pacific Island governments to identify and assess local and regional opportunities and to seek early inclusion of representatives in decision networks.
3. Industry—to input legislative and regulatory initiatives and (as noted above) to prepare to make market-based and market-timed engineering and investment decisions.
4. Environmentalists and other public interest groups and academia—to facilitate informed, effective anlaysis and constructive advocacy.

The U.S. Geological Survey of the Interior Department, and the National Ocean Survey of NOAA are to be commended for the good and highly productive cooperation which recently has characterized their work in the EEZ. The results of their work have been in recent months nothing short of spectacular, despite the deliberately systematic and fundamental nature of that work. Particularly frustrating to at least this member of industry is that these revolutionary advances are being made by government agencies with little input from industry whose budgets are so limited in this exciting time of fundamental rethinking of geological processes and of discoveries of unique mineralogical phenomena which so contribute to this intellectual ferment. There will soon come a time, however, when commercial disciplines will be useful to the proper planning of follow-on programs. I can only hope that market conditions improve so that industry can rise to that occasion.

The private sector is participating minimally in several early efforts at understanding EEZ minerals opportunities and shaping EEZ hard mineral requirements (scientific, engineering, legal). OMA employees have participated on several EEZ mapping cruises of the NOAA vessels SURVEYOR and DAVIDSON. NOAA personnel (and others from academia and the environmental community) have been invited to joint OMA cruises in the past on a voluntary basis and the cross-pollination, cooperation, and shared data bases have proved useful to all parties. In addition, OMA has proposed to the Department of the Interior several innovative, proprietary technical methods and means adapted to EEZ cobalt-rich crusts:

1. A survey tool to measure, on a continuous basis, crust thickness.
2. A unique "pyramid" box corer to recover large samples of crust and substrate.
3. An innovative mining system which discriminates between the valuable crust and the underlying substrate.

Of equal importance to the future implementation of EEZ policy, are the "priority area" working groups among federal and specific state governments, which are working on specific EEZ opportunities with the advice of academia, industry and public interest groups. These working groups are busy studying issues, planning and implementing action programs which are needed to prepare for future EEZ hard mineral mining activity in priority areas identified in the EEZ (one is the Hawaii-Johnston Island area, the other is the West Coast area). These and other efforts, under reasonable regulation and practice, may also serve to identify the presently unforeseen hard mineral opportunities which will surely be exposed by future industry and government activity in and on the seabeds of the EEZ.

None of this activity will be productive, however, unless there is a hard minerals regulatory regime in place which does not discriminate against marine mining operations, and under which regulatory actions and permitting instruments are predictable and legally defensible. OCSLA, as noted above, contains policy imperatives and administrative biases which would threaten or impose disincentives and "unpredictables" of this nature. Additionally, current events would indicate that the OCSLA process, as evidenced by recent delays in oil and gas nominations, rejections of bids, and wholesale moratoria agreements, does not produce the degree of consensus required for predictable and defensible government action on new permitting. The marine hard minerals R&D industry has observed this and has advised government of the need for a different approach. New policies and procedures need to be explored for application to hard mineral regulation in ways which will not inadvertently impact oil and gas regimes currently in place.

If one reviews the above list of required data one can see that most of this data, and indeed some of the technology needed to collect the data, does not presently exist. Collection of much, if not all, of this data is and has traditionally been, a function of government as one can discover in the surveying notes of the young George Washington, in the journals of Lewis and Clark, and the later records of a range of government programs from those of John Wesley Powell to those of General Pickett in Puget Sound, Admiral Byrd in the Antarctic, and more recently, the Apollo astronauts on the Moon.

To recapitulate, in order for government to make necessary EEZ policy decisions, laws, and regulations, and for industry to make investment decisions and operational plans regarding EEZ hard mineral resources, certain bodies of data (and in some cases the methods and means to acquire that data), which do not now exist, are needed in common:

1. EEZ Topography and Geology Maps.
1. EEZ Hard Mineral Resources Reconnaissance Data.
3. EEZ and DEEP SEABED "Second-Generation" Exploration and Mineral Assessment Tools.
4. EEZ Environmental Baseline Data.
5. EEZ and DEEP SEABED "Second-Generation" Environmental Sampling Tools.

As noted earlier, industry has developed, in its deep seabed activities, many of the skills and tools needed for accomplishing some of the above work. In many cases these skills and tools are deployable, or adaptable, to work in the EEZ. Other techniques, equipment and technical programs are being productively deployed in the EEZ by academia and the Departments of Commerce and Interior. Cooperation and joint effort between government, academia, and industry can improve this pool of skills and technical assets, better identify common activities and goals, encourage communication and a degree of commonality of data formatting practice, and reduce redundancy of efforts. These results, in turn, will assure significant increases in efficiency of effort and effectiveness of result to the benefit of all.

Government has likewise developed modern deep seabed marine hard mineral legislation, regulations, and associated administrative skills in the deep seabeds which are useful models for the EEZ. These should be studied cooperatively, modified and supplemented as needed, and drafted into new law as appropriate to achieve an environmentally acceptable incentive regime for hard mineral mining in the EEZ.

For this reason, OMA recommends cooperative and early action among federal (DOI & NOAA), state, territorial and local governments, environmental and other public interest groups, academia, and experts of the oil and hard minerals industries to study and recommend how to:

1. Identify EEZ hard mineral opportunities, problems and issues.
2. Establish the identities and needs of parties with an interest in the subject matter.
3. Educate and involve those parties in the decision-making network.
4. Assess policy options and alternative regulatory models.
5. Assist Congress to achieve the necessary statutory and regulatory framework.

The objective of such an exercise would be the consensus which is presently so lacking in marine resource affairs.

STATEMENT OF ROBERT W. KNECHT, CONSULTANT IN OCEAN AND COASTAL POLICY

Mr. Knecht. Madam Chairwoman, it's a pleasure to be here this morning and to talk about the reauthorization of this important legislation. As the agenda suggests, I earlier had a role when I was a staff member of NOAA in the early implementation of the legislation. And I had the impression at that time, and still do, that Congress wrote a very comprehensive and substantial piece of legislation when it authored the act in 1980.

I want to speak to two points briefly in this summary, and ask that my full statement be inserted into the record.

Ms. Mikulski. So ordered.

Mr. Knecht. One point elaborates on Congresswoman Schneider's question earlier; "What have we learned from earlier experience with ocean resource management programs in this country?" There have been two substantial ocean resource programs underway; one in fisheries, and one in oil and gas. And I think that we can learn a lot, by comparing the experience with those two programs.

In the case of fisheries management, we have a cooperative, collaborative, coastal State-Federal agency management approach through the regional fisheries management councils, Madam Chairwoman, and that has worked reasonably well. The amount of conflict in fisheries conservation and management is relatively small.

On the other hand, we have the OCS Oil and Gas Program, where the management decisions are undertaken by a single Federal agency, the Minerals Management Service of the Department of the Interior and I think we have to say that the amount of conflict, litigation, and delay in that program has been substantial.

We can learn from those two cases. What we need to do as we consider this new regime is to forge a cooperative approach, a real and full partnership between the coastal States and the Federal Government in this new area of endeavor. Only with a full partnership will we have a harmonious program when ocean mining comes on line.

I'm here this morning representing the coastal States, and the second part of my statement deals with how the legislation deals with the coastal States.

In 1980, when the legislation was first enacted, it was felt that the coastal States would be able to play their regulatory role through the Federal consistency provisions of the Coastal Zone Management Act. These provisions give the coastal States a role in any Federal activity that affects their coastal zones.

However, two recent judicial decisions have seriously called into question the effectiveness of the CZM Federal consistency provisions as a way of bringing coastal States into the process. A 1984 January Supreme Court decision weakened Federal consistency as it might apply to Federal activities beyond the territorial sea, and on October 11 of this year, a district court judge in California made a ruling that seriously weakens the extent to which Federal consistency applies to Federal licenses and permits, in this case, for offshore oil and gas development.

Given this record, it seems to me that we have now to go back and explicitly amend this legislation with regard to the role of coastal States. We cannot rely on Federal consistency in the way it was thought appropriate in 1980.

I would urge you, therefore, as you consider reauthorization, to look at the judicial record, to look at the uncertainties that now exist in the coastal zone management program because of these interpretations, and to consider explicitly building in the kind of coastal State partnership that ocean mining is going to require. Coastal States will be affected by these activities. There will be shoreside impacts; there will be impacts of the freighters carrying the ore through the territorial sea, and, even the ocean mining site itself and how it's developed will be of concern to the coastal States. All of those aspects, I think, need to be built into the legislation.

And finally, we would urge you to take a look at the legal—jurisdictional gap that exists at the moment between the outer edge of the geological continental shelf and the 200-mile limit. There is an uncertainty in this region with regard to the legal regime that should apply to hard minerals activities, at least in the minds of many people. Everyone wants legal stability and predictability. The industry needs it, the coastal States need it, the Federal Government needs it. Your committee would be doing a service by clearing up any existing ambiguity and putting in place an appropriate legal regime for hard minerals activities beyond the continental shelf and inside the 200-mile limit.

Thank you.

Ms. MIKULSKI. Thank you, Mr. Knecht, for your testimony.

[Statement of Mr. Knecht follows:]

STATEMENT OF ROBERT W. KNECHT, CONSULTANT IN OCEAN AND COASTAL POLICY, SANTA BARBARA, CA

Madame Chairman, it is a great pleasure for me to be invited to appear before your subcommittee today on the reauthorization of the Deep Seabed Hard Minerals Resources Act of 1980. I had the pleasure, at an earlier stage of my career, of heading the National Oceanic and Atmospheric Administration office charged with the implementation of this important piece of legislation. It was my impression at the time, that Congress, on the whole, had done a remarkably good job of drafting the legislation—of balancing our domestic interests with our international responsibilities—and of balancing the need to encourage the continued development of seabed mining technology with the clear requirement to protect the sensitive marine environment and its ecosystems from unacceptable risks.

I appear here today, Madame Chairman, as a representative of the coastal states and territories of the U.S. The positions taken in my statement embody some of the concepts that are coming out of a study being undertaken by the Coastal States Organization (CSO), for which I am the principal consultant. The study was triggered by the 1983 proclamation of a U.S. 200-mile exclusive economic zone (EEZ) and is aimed at understanding the long term implications of this new ocean zone. Emphasis is being placed on the examination of federal-state relationships in ocean affairs and on the prospects for creating a more effective and more positive partnership between these levels of government in the field of ocean management.

The interest of the coastal states in the conservation and development of ocean resources has, of course, been evident for some time. Most coastal states have been involved in the management of fisheries in the territorial sea adjacent to their shores for several decades or more. In the mid to late 60's management attention began to be focused on coastal wetlands and subsequently, on the broader challenge of shoreline management in general. The Coastal Zone Management Act of 1972 encouraged and assisted states in the formulation and implementation of comprehensive coastal zone management (CZM) programs for their shorelines and territorial seas. By the mid to late 70's, the CZM programs of most states were well advanced and a dozen or so states were, together with the federal government, wrestling with the problems of offshore oil development and its rational management.

As early as the mid-70's both Hawaii and California were beginning to factor the possibility of ocean mining into their coastal planning efforts. Both states undertook studies looking at the special problems that the processing and refining of manganese nodules in their coastal areas might bring. In Hawaii, in particular, the orientation of the studies was by no means negative—the potential economic benefits of this kind of ocean development were of considerable interest to the state.

In the ten years following those early coastal state studies, the emphasis shifted to the international and national arenas—to the marathon seabed mining regime negotiations at the Third United Nations Law of the Sea Conference and the enactment and implementation of the U.S. domestic seabed mining legislation as a working alternative to the LOS Convention that eventually emerged. The continued depression in world metals markets also decreased coastal state interest in the prospect for near-term ocean mining. However, that interest has been reawakened in recent years with the discoveries of polymetallic sulfide deposits and cobalt-rich crusts off the West Coast and near Hawaii.

After an early abortive attempt to lease the Gorda Ridge off the coast of Oregon, the federal government (the Department of Interior) regrouped and formed joint federal-state working groups to oversee some of the research and surveying activities and to assist in the preparation of the environmental impact statements which must precede any leasing. To the best of my knowledge, however, there has been no consideration of the role that the coastal states should play in the actual leasing itself or in setting the terms and conditions for ocean mining operations. Madame Chairman, I urge that your subcommittee look into this issue as a part of your deliberations on the reauthorization of this legislation. The remainder of my statement will be devoted to some comments and suggestions in this regard.

As the coastal states contemplate the beginning of a new ocean activity such as ocean mining, they see it against the backdrop of their experience with the two major on-going federal-state ocean exploitation programs—fisheries conservation and management and the OCS oil and gas program. It is instructive to note just how different these programs are in the kind of "wet federalism" that they embody. The Magnuson fisheries Conservation and Management Act (FCMA) created a joint federal-state approach to fisheries management in the 3 to 200 mile fishery conservation zone. For the most part, key management decisions are taken by councils made up of representatives of federal and state governments, the industry, and others. The OCS oil and gas program, on the other hand, is managed in its entirety by an agency of the federal government (the Minerals Management Service of the Department of the Interior), although opportunities for input from affected interests, including coastal state governors, are built into the legislative framework. The adequacy of this consultation process, however, continues to be controversial and litigation and delay continue to surround the program. While the fisheries management program is not without its own occasional conflicts, most observers feel that the cooperative arrangements built into that ocean resources management program are working reasonably well.

In general, coastal states have three kinds of interests in the development of ocean resources which they endeavor to protect or enhance in the management process—interests which are somewhat independent of whether the activity is in state or federal waters.

Economic.—The activity can be of significant economic benefit to the adjacent coastal state (i.e., fisheries) or it can tend to displace or, in other ways, adversely impact other ocean activities of significant economic benefit to the state and its communities.

Shoreside Support Needs.—All ocean development activities ultimately need a shore connection for processing, marketing, resupply, etc. These shoreside support needs can result in economic benefits to local interests or they can cause competition for limited coastal space and facilities and, ultimately, displacement.

Environmental Impacts.—Impacts on the marine environment and other ocean and coastal resources can be associated with ocean development activities. States must be interested in the direct and indirect environmental consequences of these activities since they could affect the physical and economic health of their citizens.

Understandably then, the coastal states now seek to be full partners with the federal government when new types of ocean resource exploitation are contemplated. They see the ocean resource development process as a system that includes three elements: the offshore exploitation activity (i.e., the ocean mining operation itself); a transportation link (i.e., transport by ore-carrying ships to port); and a shoreside processing facility (i.e., an industrial facility to extract the metals from the ore and begin the transport of the refined products to market). Just because an ocean mine site may be located in federal waters (or beyond), does not mean that there is not a strong coastal state interest in the way in which the mineral deposit is exploited. Indeed, because the three elements of the system are inextricably linked, the coastal state, at the receiving end of the system, must be a full party to decisions that affect the volume of ore moving through the system (the "throughput"). Hence, the coastal state is legitimately concerned with the scale of ocean mining activity (size of the mine site, rate at which mining takes place, etc.). Similarly, the coastal state must be interested in the scheme that will be used to transport the mined ore to shore and the implications of the transport system on other ocean activities of economic importance to the state. The demands and stresses that the transport scheme places on port and harbor facilities will also be of concern. Finally, of course, state and local authorities will have major interest in the shoreside facilities proposed by the mining companies and their resource demands and environmental impacts.

Coastal states are experimenting with the concept of "shore-linkedness" as one of the principles that might be useful in attempting to rationalize the roles of the state and federal governments in ocean development. The nature of the link between the ocean activity and the shoreland, together with the scale and nature of the demands being placed on the shoreland, would determine the degree of coastal state involvement with the federal government in the decision-making concerning the ocean development project. Congress has already set certain precedents in this regard—in the Deepwater Ports Act of 1974 and the Ocean Thermal Energy Conversion Act of 1980. In both situations, the ocean activity is directly linked with the shoreland—in the deepwater port case, by a pipeline to shore and in the OTEC case, by an electrical cable. In both cases, Congress has required the concurrent approval of the adjacent coastal state before the federal government can act. In other words, true ocean development partnerships are called for in these pieces of legislation.

With regard to ocean mining, it would seem that a larger scale mining project which has a high and more or less continuous level of mineral ore throughput, represents a system that is "linked" in most of its essential aspects to the shoreland. A continuous stream of ore is produced at the ocean mine site and transported and deposited at the shoreland end of the system. Continuity in operation and virtually continuous flows all along the system are required for a successful venture. Hence, it seems to us that state and local governments, having jurisdiction over the territorial sea and shoreland portions of the system, as they do, and having strong interests in the activity as shown above, must be *full partners* with the federal government and industry in this kind of ocean development. Precisely what this means in terms of the state role in the decision-making process is still under consideration but certain general conclusions seem clear:

Coastal states need to have a significant role in setting the environmental standards that will apply to ocean mining operations in a given area, especially as those operations might affect other ocean activities of major interest to the states;

Coastal states need to have a significant role in setting the scale of ocean mining activities, since the volume of throughputs is of direct and immediate interest to affected states;

Coastal states need to have a significant role in the approval of individual ocean mining projects, including the terms and conditions placed on these projects, in order to insure that other ocean activities also of interest to the state are not unduly impacted by the ocean mining project. Although no position has yet been taken, the possibility of proposing that a portion of federal revenues that may be generated by the sale of ocean mining leases be shared with directly affected coastal states, is also under study.

A final point, Madame Chairman, involves the need for a clearly defined domestic legal regime which applies to that portion of the seabed lying seaward of the geological continental shelf but within our 200-mile EEZ. While not wishing to take a position on the issue of agency jurisdiction at this time, it seems clear that the Deep Seabed Hard Mineral Resources Act contains approaches that are appropriate to the special needs of deep seafloor mining, whether the deposits be nodules, sulfides, or crusts. The Outer Continental Shelf Lands Act Amendments were designed for offshore oil and gas exploration and exploitation and do not appear to be easily applicable to the ocean mining situation. We hope that you address this gap in your deliberations.

In closing, Madame Chairman, we urge that your subcommittee consider the needs of the coastal states as you consider the reauthorization of this legislation. We should benefit from our experience with other ocean programs and endeavor to create an ocean mining program that is stable in its processes and leads to fair and equitable outcomes. Specific recommendations from the coastal states on this matter will be contained in a report presenting the final results of the CSO EEZ study. That report and its recommendations should be available shortly after the end of the year. Thank you.

Ms. MIKULSKI. The committee will now move to questions, and of course any additional comments that the gentleman from South Carolina would like to make. I'm going to ask the most abled gentleman from South Carolina to take the chair, and we thank you for your testimony.

Mr. TALLON. Gentlemen, thank you for your testimony. Mr. Peck, you've described the activities of the U.S. Geological Survey in surveying the mineral resources of the exclusive economic zone.

How would you describe NOAA's efforts and contributions to the work of mapping and surveying the EEZ and discovering its mineral resources, and how does this work carried out by NOAA compliment your agency's work on the EEZ?

Dr. **Peck**. Mr. Chairman, the work of the two agencies is complimentary. Basically we have divided our responsibilities in that NOAA has the responsibility for the water column and its chemistry and the bathymetry of the seafloor. We have responsibility for the rocks underlying the seafloor, and we work together along the mudline in between.

For example, in the polymetallic sulfides, for our work we need the detailed bathymetry that NOAA is gathering, and we help supply some funds so that the bathymetry can be generated more quickly.

The work that NOAA has carried out in cooperation with Oregon State University, to study the chemistry of the waters above the rift zone, helps to identify sources of vents so that we can go in and look more closely and try to sample those vents. In most of the voyages we have some of our scientists on their ships and they have some scientists on our ships, and we both have university scientists with us. So, we are all working pretty closely together and in a complementary fashion.

Mr. **Tallon**. What recommendations did you make toward improving the cooperative efforts of NOAA and the U.S. Geological Survey in surveying the resources of the EEZ?

Dr. **Peck**. Well, we have worked pretty hard over the last several years to improve that coordination. I think we worked with Dr. John Byrne, when he was Administrator, very effectively, and now are continuing to do so with Dr. Tony Calio. My Associate Director, Doyle Frederick, and I have had many meetings with just the four of us, meetings to discuss our problems and how we could work more closely together. And out of that has grown a far better working arrangement.

Offhand, I do not see how we could have improved it. Perhaps Mr. Paul Wolff would have some suggestions. We are doing OK? There.

Mr. **Tallon**. Well, that's good. Thank you very much. Mr. Greenwald, there seems to be a theme running through much of the testimony here, and that theme is that it will be 10 or 15 years before we begin commercial mining on the deep seabed or in the exclusive economic zone. So, we have enough time to think through what kind of ocean mining program we need.

What do you think our priorities should be to encourage the development of this potentially valuable industry, and what do we need to do, and when do we need to do it?

Mr. **Greenwald**. Leadtimes in the hard minerals industry are quite frequently 15 to 20 years from the inception of a project until the first positive cash-flow, which is the important event that my company has not achieved in 23 years.

If we're talking a 15-year leadtime, we need now to do two things. We need to get that information base which we've talked about today. That is going on presently and it's quite a good program. We also need to achieve the regulatory regime in the same timeframe, so that those two streams are going together; the fundamental data and informed legislative action. These will create the predictable economic environment that industry needs to make significant investments in EEZ hard mineral development.

Mr. TALLON. Thank you, sir. Mr. Knecht, I know you were the first director of NOAA's Ocean Minerals Program. In your view, what advantages do you see in managing EEZ resources under legislation similar to the Deep Seabed Act as opposed to the Outer Continental Shelf Lands Act, or would there be any advantage?

Mr. KNECHT. Oh, yes. I think in the hearing this morning there have been numerous references to the differences between activities involving the exploration and exploitation of hard minerals, on the one hand, and oil and gas, on the other. The Oil and Gas Program is well served a high risk, high gain approach where the leasing tract grid is superimposed on the surface of the ocean, if you will, and people take their chances on oil discoveries as their drills penetrate the seafloor a mile or so down, and then go another 3 or 4 miles into the seabed.

The oil companies I think like the game of trying to get promising offshore tracts for the lowest possible bid and then, hopefully, discovering large deposits. It's all one grand gamble. However, it seems to me that hard minerals exploitation is of a different nature. When the scientific research, the surveys, and the exploration are done, pretty good information on what exists there is in hand. There may be some technological uncertainties on how well the mining equipment is going to work over time and so on, but, in general, you know it's there. So, the entire economic relationship between the Government and the mining industry would be a very different one. And that's just one example. There are numerous others.

It seems to me the Deep Seabed Hard Mineral Resources Act was tailored for the hard minerals problem and should now be adapted to EEZ minerals. I think it would be totally inappropriate to try to adapt an oil and gas approach to this problem.

Mr. TALLON. Thank you very much, and I thank all of you for your testimony this morning. It's been a very productive hearing. The subcommittee will now stand adjourned.

[Whereupon, the hearing was adjourned at 11:30 a.m.]

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